



**Office of the Secretary of Defense**

**Airspace Integration Plan  
for  
Unmanned Aviation**

**November 2004**

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>NOV 2004</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Airspace Integration Plan for Unmanned Aviation</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Under Secretary of Defense 3010 Defense Pentagon Washington, DC 20301-3010</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>The original document contains color images.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>UU</b>	18. NUMBER OF PAGES <b>80</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			





ACQUISITION,  
TECHNOLOGY  
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## THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON  
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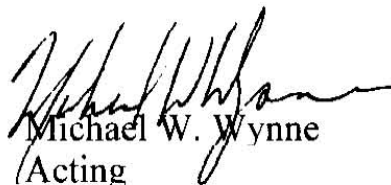
MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS  
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SUBJECT: Airspace Integration Plan for Unmanned Aviation

The Department's *Airspace Integration Plan for Unmanned Aviation – November 2004* establishes top-level timelines and program milestones to achieve safe, routine use of the National Airspace System (NAS) by Department of Defense Unmanned Aerial Vehicles (UAVs).

This plan differentiates among categories of UAVs with respect to airspace requirements, and clearly states that it is the *Service's role* to qualify operators/pilots and self-certify UAV systems. It discusses the regulatory and technology issues that must be addressed to achieve safe, routine access to the NAS for the Department's UAVs by 2010.

While it is a Department of Defense plan, it also provides a foundation for other federal and international organizations in pursuit of integrating manned and unmanned aviation within domestic and international airspace.

  
Michael W. Wynne  
(Acting)



## Executive Summary

The Office of the Secretary of Defense *Airspace Integration Plan for Unmanned Aviation* outlines the key issues that must be addressed to achieve the goal of safe, routine use of the National Airspace System (NAS) by Department of Defense (DoD) Remotely Operated Aircraft (ROA)<sup>1</sup>. It is based upon ongoing work performed in support of the joint Office of the Secretary of Defense-Federal Aviation Administration (OSD-FAA) Unmanned Aerial Vehicle (UAV) Airspace Integration Initiative.

The Airspace Integration Plan is intended to provide the reader with background information, program status, and goals for the integration of military ROA into the United States' National Airspace. Integration of unmanned and manned aircraft for military operations, and ROA operating procedures are subjects beyond the scope of this document. The information detailed in this plan is based on a survey of existing technologies and regulations as well as proposed development and support for new solutions as required. To achieve full integration of military ROA by the desired 2010 timeframe, the plan identifies six critical regulatory and technology issues that must be addressed before safe and efficient integration can occur.

- Air Traffic (see Section 3.1)
- Airworthiness Certification (see Section 3.2)
- Aircrew Qualification (see Section 3.3)
- See-and-Avoid (see Section 4.1)
- Command, Control, Communications (see Section 4.2)
- Reliability (see Section 4.3)

Because military ROA will increasingly operate outside of Special Use Airspace (SUA), UAV-related military technology and regulations must be sensitive to other airspace users. Coordination of both domestic and international airspace efforts that are being conducted in parallel to the OSD-FAA effort is necessary. These efforts are not only leveraging previous accomplishments of the OSD-FAA effort, but are also contributing to it on technical and regulatory levels. Such efforts in the commercial and civil arenas reduce the burdens that accompany the successful integration of military ROA into the NAS by facilitating technology development, common ROA standards/airworthiness, cost-effectiveness, reliability, and public acceptance.

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<sup>1</sup> While "Unmanned Aerial Vehicle (UAV)" is a universally recognized term that encompasses a spectrum of aircraft that are autonomous, semi-autonomous, or remotely operated, the Federal Aviation Administration has historically used the term "Remotely Operated Aircraft (ROA)" for matters dealing with airspace.

Based on the existing and planned infrastructure, technology, and regulations presented, the *OSD Airspace Integration Plan* establishes top-level timelines and program milestones in context and relation to the FAA's strategic plans. It also serves as both a reference document and precedent for other U.S. government organizations and non-U.S. entities that are currently conducting their own airspace-dependent programs or plan to do so in the future.

# Airspace Integration Plan for Unmanned Aviation

November 2004

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# Airspace Integration Plan for Unmanned Aviation

November 2004

## 1.0 Overview

### 1.1 Introduction

Military UAVs<sup>2</sup> have historically been flown in restricted airspace (over test and training ranges) or war zones, and have thus largely avoided coming into conflict with manned civilian aircraft. This is changing. The United States' National Airspace System (NAS) must be shared by all users, manned and unmanned, to support national defense, homeland security, and other civil and commercial operations. Unmanned aerial vehicles (UAVs) must be seamlessly integrated into the current NAS infrastructure while enabling safe, efficient, and effective operations. Since the 11 September 2001 terrorist attacks, airspace security has become an equal priority with safety, and the operation of military UAVs for homeland defense in the NAS outside of restricted airspace increasingly is being considered.

To this end, there are six key UAV-related regulatory and technology issues which must be addressed by the Department of Defense, to include

- Air Traffic (see Section 3.1)
- Airworthiness Certification (see Section 3.2)
- Aircrew Qualification (see Section 3.3)
- See-and-Avoid (see Section 4.1)
- Command, Control, Communications (see Section 4.2)
- Reliability (see Section 4.3)

The following *Airspace Integration Plan for Unmanned Aviation* details these issues and key drivers that must be addressed to achieve the goal of safe, routine use of the national airspace by DoD UAVs. It is based upon ongoing work performed in support of the joint Office of the Secretary of Defense-Federal Aviation Administration

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<sup>2</sup> While "Unmanned Aerial Vehicle (UAV)" is a universally recognized term that encompasses a spectrum of aircraft that are autonomous, semi-autonomous, or remotely operated, the Federal Aviation Administration has historically used the term "Remotely Operated Aircraft (ROA)" for matters dealing with airspace. "ROA" and "UAV" are used interchangeably in this document.

(OSD-FAA) UAV Airspace Integration Initiative (also referred to as the OSD-FAA airspace effort).

## **1.2 Purpose**

The general purpose of this plan is to outline the regulatory and technical infrastructure necessary for DoD to integrate military unmanned with manned flight operations in the NAS. Specific motivation for this goal can be seen by examining specific requirements of current military UAV programs. These requirements include the capability of controlling several air vehicles by a single operator from one control station, and worldwide operations; and set significant new precedents for future UAV operations in the NAS.

While much work in UAV airspace integration is being addressed by the joint OSD-FAA airspace effort, this plan also highlights other work currently underway relating to the OSD-FAA airspace effort. It also identifies those areas that are yet to be addressed and outlines key top-level milestones.

## **1.3 Vision**

The OSD vision is to have “File and Fly” (F&F) access for appropriately equipped UAV systems by 2005 while maintaining an equivalent level of safety (ELOS) to that of an aircraft with a pilot onboard. For military operations, UAVs will operate with manned aircraft in and around airfields using concepts of operation that make on- or off-board distinctions transparent to air traffic control authorities and airspace regulators. The operations tempo at mixed airfields will not be diminished by the integration of unmanned aviation. Positive aircraft control must be assured through secure communications and established procedures for UAVs operating in the NAS.

## **1.4 Approach**

### **1.4.1 Precepts**

Certain guiding principles have been established in pursuit of this vision. These principles can be stated as follows:

- **Do no harm** – Avoid new initiatives; enacting regulations for the military user that would adversely impact 1) the Services’ right to self-certify aircraft and aircrews, 2) air traffic control practices or procedures, 3) manned aviation CONOPs or TTPs; or unnecessarily restrict civilian or commercial flights. Where feasible, leave “hooks” in place to facilitate the adaptation of these regulations for civil use. This also applies to recognizing that “one size does NOT fit all” when it comes to establishing regulations for the wide range in size and performance of DoD UAVs.
- **Conform rather than create** – Interpret the existing Title 14 Code of Federal Regulations (CFR) (formerly known as Federal Aviation Regulations, or FARs) to also cover unmanned aviation and avoid the creation of dedicated UAV

regulations as much as possible. The goal is to achieve transparent flight operations in the NAS.

- **Establish the precedent** – Although focused on domestic use, any regulations enacted will likely lead, or certainly have to conform to, similar regulations governing UAV flight in International Civil Aviation Organization (ICAO) and foreign (specific countries’) airspace.

### 1.4.2 Process Overview

A joint effort was started in 2002 by OSD and the FAA, specifically the Air Traffic, Flight Standards, and General Counsel offices within FAA, and OUSD(I) and OUSD(AT&L) within the Pentagon. The three-phase approach is discussed in more detail in Section 5.1. The joint OSD-FAA effort focuses on the following three accomplishments that are intended to enable the vision:

- Enable routine access to the NAS (Regulatory Phase)
  - Leverage existing procedures for manned flight operations; use current guidance for unique military operations as outlined in FAA Order 7610.4 as a path for NAS integration
- Define standards for DoD sense-and-avoid (S&A) system. (Technical Phase)
- Demonstrate the F&F process and S&A system in a series of UAV flights among FAA regions. (Implementation Phase)

## 1.5 Definitions

The following definitions are provided to clarify the terms which will be used in this plan.

- *Aircraft*: a device that is used or intended to be used for flight in the air [14 CFR Part 1]
- *Remotely Operated Aircraft (ROA)* a powered, aerodynamic aircraft with an integral recovery/landing system which is operated without a pilot onboard. ROA are divided into three categories:
  - *Cat I* – an ROA similar to a Radio-Controlled (RC) model aircraft.
  - *Cat II* – an ROA that does not fully comply with airspace equipage requirements and is not used similarly to RC model aircraft.
  - *Cat III* – an ROA that complies with applicable parts of 14 CFR Part 91.

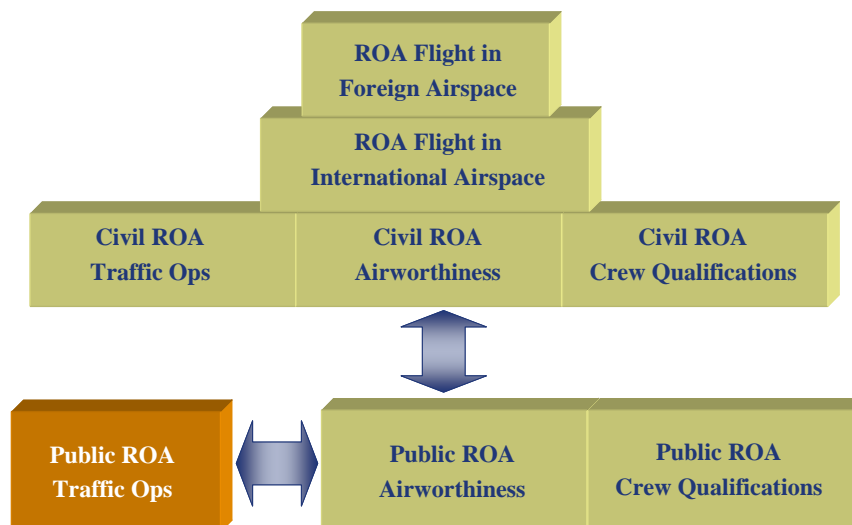
- *Public aircraft*: an aircraft used only for the United States Government, or owned and operated (except for commercial purposes)...[14 CFR Part 1]<sup>3</sup>
- *Civil aircraft*: an aircraft other than public aircraft [14 CFR Part 1]

As indicated, an aircraft can be categorized as either public or civil, with the correct classification being mission-, rather than user-, specific. The envisioned regulatory baseline for operating military ROA in civil airspace is provided in Section 6.2.

The FAA currently regulates a wide spectrum in characteristics (weight, propulsion type, etc.) and performance (speed, altitude, etc.) of aircraft. The characteristics and performance of ROA are a subset within this spectrum, whether for those designed from the outset to be unmanned or those converted ("demanned") from manned to unmanned operation. For this reason, the existing FAA regulatory structure appears to need little adaptation to accommodate unmanned aviation terminology.

## 1.6 Scope

OSD and FAA, working through the DoD Policy Board on Federal Aviation (PBFA), are engaged in establishing the air traffic regulatory infrastructure for integrating military ROA into the National Airspace System (NAS). By limiting this effort's focus to *traffic management* of *domestic* flight operations by *military* ROA, it is hoped to establish a solid precedent that can be extended to public and civil ROA domestically and to civil and military flights in international and non-US airspace. As depicted in Figure 1-1, this initiative (shown by the lower-left block below) is intended to serve as the first brick in the larger, interwoven wall of regulations governing worldwide aviation.



<sup>3</sup> A more extensive definition is available in 14 CFR Part 1

### **Figure 1-1: Groundwork for OSD-FAA Airspace Effort**

The OSD-FAA effort is not intended to address airworthiness issues (covered by the Operational Safety, Suitability, and Effectiveness [OSS&E] process) and aircrew qualifications issues (covered by Service-specific rules) of military UAVs. These and other issues are presented, when necessary, in order to provide the context in which the OSD-FAA effort has progressed. This plan in no way impacts the DoD's right to self-certify military aircraft and pilots.

## 2.0 Infrastructure

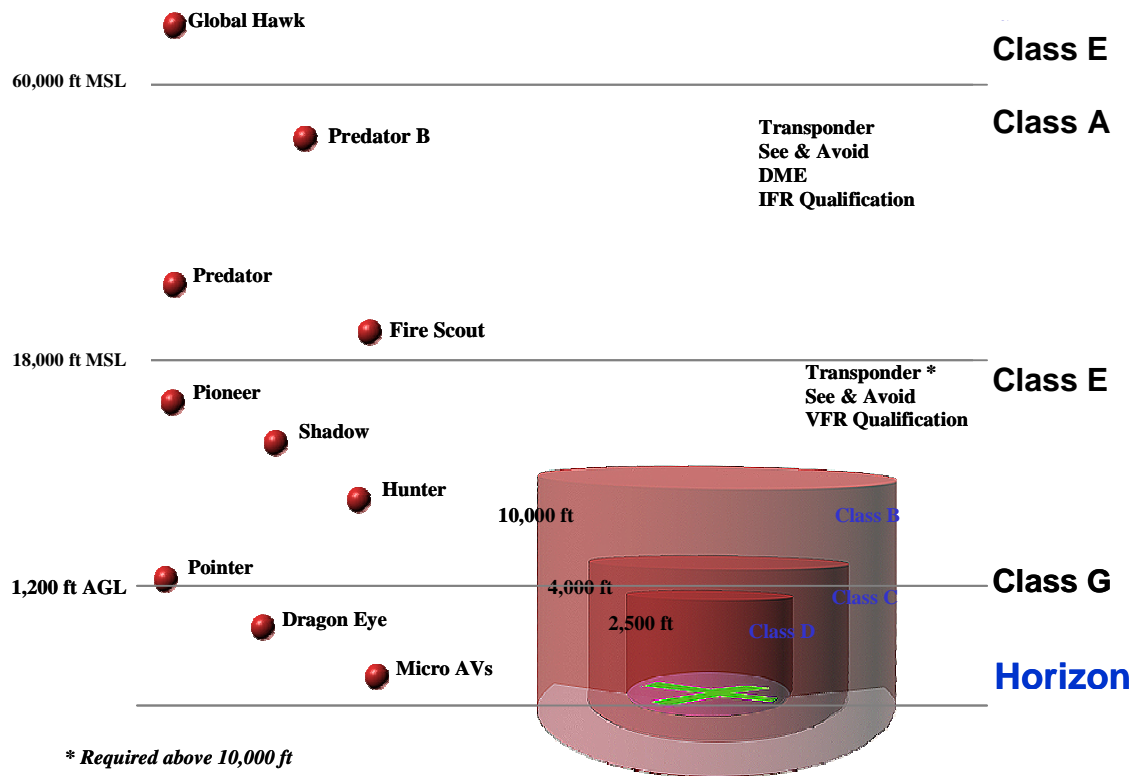
### 2.1 *Airspace*

There are six defined classes of airspace in the U.S. that are controlled in various degrees by the air traffic control (ATC) infrastructure. Because these classes are referenced throughout this document, a brief discussion is useful.

- **Class A** airspace exists from Flight Level (FL) 180 (18,000 feet Mean Sea Level (MSL)) to FL600 (60,000 feet MSL). Flights within Class A airspace must be under Instrument Flight Rules (IFR) and under the control of ATC at all times.
- **Class B** airspace surrounds several major airports (generally up to 10,000 feet MSL) to reduce mid-air collision potential by requiring ATC control of IFR and VFR (Visual Flight Rules) flights in that airspace.
- **Class C** airspace surrounds busy airports (generally up to 4,000 feet Above Ground Level (AGL)) that do not need Class B airspace protection, and requires flights to establish and maintain two-way communications with ATC while in that airspace. ATC provides radar separation service to flights in Class C airspace.
- **Class D** airspace surrounds airports (generally up to 2,500 feet AGL) that have an operating control tower. Flights in Class D airspace must establish and maintain communications with ATC, but VFR flights do not receive separation service.
- **Class E** airspace is all other airspace in which IFR and VFR flights are allowed. Although Class E airspace can extend to the surface, it generally begins at 1200 feet AGL, or 14,500 MSL, and extends upward until it meets a higher class of airspace (A-D). It is also above FL600.
- **Class G** airspace (there is no Class F airspace in the U.S.) is also called uncontrolled airspace because ATC does not control aircraft there. Class G airspace can extend to 14,499 feet MSL, but generally exists below 1200 feet AGL, and below Class E airspace.

Accordingly, Classes B, C, and D relate to airspace surrounding airports where increased mid-air collision potential exists; Classes A, E, and G primarily relate to altitude, and the nature of flight operations that commonly occur at those altitudes. ATC provides separation services to all flights in Classes A, B, and C. They provide it to some flights in Class E, and do not provide service in Class G. Regardless of the class of airspace, or whether ATC provides separation services, pilots are required to “see and avoid other aircraft” whenever weather permits.

Various types of ROA/UAVs have the capability to fly through each of these classes as depicted in Figure 2-1.



**Figure 2-1: Airspace Classes and Typical ROA Performance**

The FAA is moving toward a two-class structure for the NAS, “terminal” and “enroute.” Terminal will subsume Class B, C, and D airspace, and Enroute will include Class A, E, and G airspace.

## 2.2 FAA Order 7610.4

Because current UAV systems do not have the same capabilities as manned aircraft to integrate safely and efficiently into the NAS, military UAV requirements to



operate outside of restricted and warning areas are accommodated on a case-by-case basis. The process used to gain NAS access was jointly developed and agreed to by the DoD and FAA in 1999 through FAA Order 7610.4, Chapter 12, Section 9. FAA Order 7610.4 specifies procedures for air traffic control planning, coordination and services during defense activities and special military operations. These procedures apply to all activities conducted in airspace controlled by or under the jurisdiction of the FAA. The procedures contained in the document shall be used as a planning guide by DoD personnel for operations in all areas. The military services have included this order into their inventory. This has been done to emphasize its applicability to DoD personnel including the National Guard and the Reserve Forces.

Statutory language within the Code of Federal Regulations does not preclude military UAV flights in the National Airspace. Rather, the limitations for military UAV flight are imposed by the Services due to the lack of appropriate equipage of these aircraft.

### **2.2.1 Certificate of Authorization (COA) process**

DoD ROA need safe, *routine* access to the NAS and ICAO airspace for training and operations. Current procedures, in accordance with FAA Order 7610.4, Chapter 12, Section 9, provide a means for DoD ROA to gain access to the NAS; however, they require an application for a COA to be filed at least 60 days prior to operations for all ROA operations outside of Restricted Areas and Warning Areas. While sufficient for ROA development activities where preplanned routes and schedules are acceptable, the COA process may not provide the flexibility necessary to accomplish the wide range of DoD ROA operations:

- DoD small hand-launched ROA currently require airspace access outside Restricted Areas and Warning Areas - the same airspace that Radio-Controlled (RC) model airplanes fly without a COA.
- An ROA's unique performance capabilities make them an ideal platform for Homeland Defense applications, routine access to unplanned areas will be critical to effective operations.
- Routine access is needed for DoD ROA transiting to operating, testing, and training areas.

FAA Form 7711-2, Application for Certificate of Waiver or Authorization, is provided in Appendix A. COAs are typically issued for one-time events, are limited to specific routes or operating areas, and are valid for no more than 1 year. An exception is the National COA that was issued to the Air Force for Global Hawk operations in the NAS. This COA is intended to facilitate Global Hawk deployments overseas as well as enhance training domestically.

### **2.2.2 Genealogy of 7610.4 (through Service regulations)**

With a COA, the ROA is accommodated into the system when mission needs dictate. However, because current ROA do not have the ability to operate as a manned

aircraft, they are at times segregated from manned aviation rather than integrated with it. The joint OSD-FAA effort is intended to address this issue. The DoD and FAA have agreed to review the current guidance contained in FAA Order 7610.4, Military Operations, and will refine or replace the COA process if mutually beneficial to both DoD and FAA. Chapter 12, Section 9 of the current 7610.4K guidance is provided in Appendix B.

This important first step is being led by the Air Force Flight Standards Agency (AFFSA). The AFFSA effort is key to the demonstration phase of the on-going OSD-FAA effort (described in Section 5.1). Specifically, as the DoD concepts of operation for UAV systems such as the Unmanned Combat Aerial Vehicle (UCAV) and Global Hawk mature, and as the airworthiness of military UAV systems is enhanced, DoD will look toward developing new procedures in order to gain access to the NAS.

## **2.3 Organizations and Roles**

There are several key organizations engaged in the development of airspace regulations and procedures with respect to ROA. A brief description of these organizations is provided below.

- **DoD Policy Board on Federal Aviation (PBFA):** The PBFA is established by Department of Defense Directive 5030.19. This directive, most recently updated on 15 June 1997, outlines the DoD organizational structure for interface with the Department of Transportation, the FAA, and other agencies on air traffic control and airspace management. In this capacity, the PBFA provides policy and planning guidance for comprehensive airspace planning in order to 1) ensure that the Military Departments have sufficient airspace to fulfill military, training, and test and evaluation requirements, 2) cooperate with the FAA for the effective and efficient management of the NAS, and 3) ensure operational interoperability between the DoD and the FAA.

The PBFA advises and assists the ASD(NII) on air traffic control, airspace management, NAS matters, joint systems acquisition, and aviation-related international affairs. Membership includes representatives at the three-star level from USD(A&T); USD(Policy); USD(C); GC, DoD; DOT&E; one representative from the Office of the Chairman of the Joint Chiefs of Staff; and one representative from each of the Military Departments. The PBFA Chair or Executive Director may convene subcommittees, subgroups or panels to support the PBFA with representatives from the organizations comprising the PBFA. The Executive Director, in consultation with the PBFA Chair and representatives from the organizations comprising the PBFA, may establish working groups and advisory bodies, as necessary, to support activities of the PBFA. The PBFA Working Group provides the mechanism for addressing medium to long-term user and interoperability requirements planning for the NAS.

The PBFA Chair or Executive Director may also invite other organizations having an interest in Federal aviation and NAS matters to be represented at the PBFA or

any of its subgroups, on an ex-officio basis, or to participate in the meetings when matters germane to their interests are addressed.

- **DoD – FAA NAS Integration Subgroup:** The DoD – FAA NAS Integration Subgroup was formed in response to direction from the Office of the Secretary of Defense Senior Requirements Oversight Council (SROC). The subgroup is co-chaired by the Executive Director, DoD PBFA and the FAA Associate Administrator for Air Traffic Services. It is comprised of members from the DoD and FAA.

This subgroup was established as a mechanism for the DoD to identify potential impacts to DoD of the FAA's NAS modernization. It will provide a mechanism for the DoD to submit input to the FAA's Operational Evolution Planning process and serve as the DoD integration focal point for the FAA's redesign planning process.

- **Air Force Flight Standards Agency (AFFSA):** The Air Force Flight Standards Agency's mission is to develop, standardize, evaluate, and certify procedures, equipment, and standards to support global flight operations and to centrally manage Air Traffic Control and Landing Systems (ATCALS) for the Air Force. This organization is a Field Operating Agency of the United States Air Force. AFFSA produces USAF-level instrument directives, flight procedures criteria, aeronautical information, and training program guidance. AFFSA standardizes current/emerging cockpit avionics/displays and provides Aircraft Accident Board technical advice. AFFSA is the USAF Terminal Instrument Procedures (TERPS) waiver authority and manages the USAF TERPS automation program. They evaluate Navigational Aid Systems (NAVAIDS) and Notice to Airman (NOTAMs) and conduct the Air Traffic Control (ATC) Facility Management School.

AFFSA also develops USAF Flight Inspection standards and procedures for the FAA. They certify National Airspace System navigational facilities (civilian and military) and associated instrument approach procedures. They are the designated Lead agency for DoD to facilitate unmanned aerial vehicle operations in the NAS with the FAA, and represent the USAF on the DoD Policy Board on Federal Aviation.

- **DoD ROA Airspace Integration Working Group:** This group is a joint panel of DoD and FAA experts chartered by the Policy Board on Federal Aviation as the lead DoD entity representing all Services' interests in order to provide a consolidated DoD input to the FAA on the operation of DoD ROA in the NAS.



## **3.0 Regulatory Background**

### **3.1 *Air Traffic***

#### **3.1.1 Terminology**

##### **3.1.1.1 14 CFR Part 91 (ROA Cat III applicability)**

Regulations for aircraft operations are well established in 14 CFR (particularly Part 91), and Service regulations. These same regulations should govern the operation of military Cat III ROA in civil airspace.

##### **3.1.1.2 14 CFR and Non-Standard Aircraft (ROA Cat II applicability)**

The FAA also recognizes many different categories of aircraft that are built and equipped differently from the standards of Normal or Utility category aircraft. The regulations and orders identify Ultralights, Light-Sport, Experimental, Restricted, and Special category aircraft, as well as Moored Balloons, Kites, Unmanned Rockets and Unmanned Free Balloons. These systems vary in size from ultralights up to firefighting tankers, but they all have specific restrictions governing how, when, and where they can operate; and specific procedures necessary to coordinate that flight.

Since some military UAVs share many operating characteristics and physical metrics with the smaller aircraft above (Ultralights and Light-Sport Aircraft), it is possible to establish a similar bracket or “category” for these UAVs. The proposal in Section 6.2 describes this category (Cat II ROA) as those that are used in a manner similar to restricted category aircraft (special purpose operations). Examples of these UAVs range from the Exdrone to the Shadow 200 and the Pioneer.

##### **3.1.1.3 FAA AC 91-57 (ROA Cat I applicability)**

The FAA defines an aircraft as “a device that is used or intended to be used for flight in the air” (14 CFR 1). While model airplanes fit this definition, there is no 14 CFR Part associated with them. The FAA has omitted them from regulation because their operations do not normally create a hazard to air navigation. The FAA does, however, publish an Advisory Circular, AC 91-57 (Appendix C), which encourages voluntary safety standards for their use.

Accordingly, it is envisioned that military UAVs having similar metrics, and operated in a similar manner to model aircraft (Cat I ROA), would only require operational restrictions (specific guidance to operate DoD ROA in areas other than restricted/warning areas is found in FAA Order 7610.4, see Section 2.2 and 2.2.1) and not any extra regulatory attention. Examples of such UAVs are the hand- or bungee-launched types such as Pointer and Dragon Eye.

### **3.1.2 Class, Category, and Type**

It is important to note that the FAA uses the term “category” in two different ways (14 CFR 1). As used with respect to the certification, ratings, privileges, and limitations of airmen, the term “category” means a broad classification of aircraft. Examples include airplane, rotorcraft, glider, and lighter-than-air. As used with respect to the certification of aircraft, the term “category” means a grouping of aircraft based upon intended use or operating limitations. Examples include transport, normal, utility, acrobatic, limited, restricted, and provisional. When discussing right-of-way rules in 14 CFR 91.113, however, the FAA uses non-mutually exclusive categories such as balloon, glider, airship, airplane, rotorcraft, and engine-driven aircraft for determining which flight has the right-of-way. 14 CFR 103 requires ultralights to yield the right-of-way to all other manned aircraft. Similarly, the FAA provides avoidance (right-of-way) advice for radio-controlled (RC) model aircraft in an Advisory Circular.

There have been several good suggestions regarding the classification and categorization of ROA for FAA consideration. Unfortunately, such classification schemes have been created from the standpoint of ROA characteristics (Micro, Mini, Tactical, Low Altitude Deep Penetration, Mid-Range Endurance, LALE, MALE, HALE, etc.) and not from the perspective of existing FAA definitions.

The FAA already classifies regulated aircraft by “Class,” “Category,” and “Type.” For example, a small airplane (Class, less than 12,500 pounds defined under Part 23) is categorized as Primary, Normal, Utility, Aerobatic, Limited, Restricted, or Transport. These categories provide a wide range of size, weight, and capability limits, paired with safety and reliability requirements that can be easily adapted to ROA. In addition, all the various parts and systems, except for the data-link and ground station, already have certification requirements and standards available. For military ROA, this provides the basis for sound general guidance for its own operational safety standards and evaluation (the OSS&E process).

Relating to this, there is discussion concerning the difference among “piloted,” “commanded,” “semi-autonomous,” and “autonomous” vehicles. This refers to the human system interface provided in the control station. The FAA already recognizes several systems on aircraft that have different implementations (e.g., side-stick vs. yoke, different autopilot capabilities, mechanical vs. “glass” attitude indicators, etc.) Each of these different systems has its own Technical Standard Order for safety and reliability, is certified as a system, and is then included in the overall aircraft certification for airworthiness and type. Similarly, the different types of control systems for ROA would be distinguished in the operator’s rating under “ratings and limitations.”

It is clear that some taxonomy for ROA is needed to define their operating privileges, airworthiness standards, operator training and certification requirements, and their place in the right-of-way rules.

### 3.1.3 ROA Taxonomy

Although *public* (e.g., U.S. military) aircraft are to some degree exempt from a number of FAA regulations such as airworthiness and pilot certification, certain responsibilities still exist.

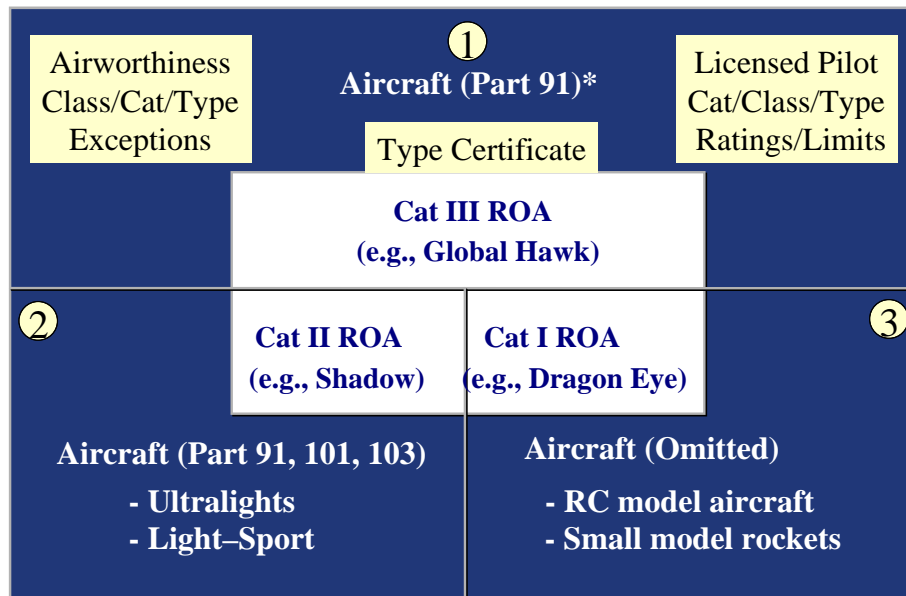
- Meeting equivalent airworthiness and operator qualification standards to operate in the NAS,
- Conforming to FAA traffic regulations (see-and-avoid, lighting, yielding right-of-way, etc.) when operating outside of restricted airspace, and
- Complying with international (ICAO and foreign) regulations when transiting their airspace, regulations which often take those of the FAA as precedents.

Military ROA with a need to routinely operate outside of restricted airspace or in international airspace must therefore make themselves transparent to air traffic management authorities. In large part, this means *conforming by exemption* to 14 CFR Part 91 for the larger ROA, such as the Air Force's Global Hawk and Predator, *as do manned military aircraft*. This plan calls for these ROA (Cat III ROA) to be treated similarly as manned aircraft.

The FAA recently approved a light-sport category in the regulations, and does not require either airworthiness or pilot certification (similar to Part 103 aircraft) for certain uses and limited operations. These aircraft achieve an equivalent level of safety to certificated aircraft with a slightly lower level of reliability. There are also many restricted category aircraft that perform special purpose operations. A number of U.S. military UAVs (U.S. Navy's Pioneer, U.S. Army's Shadow and Hunter) share similar characteristics and performance. This plan calls for these ROA (Cat II ROA) to be treated similarly to ultralights, light-sport, or restricted category aircraft.

As a final case with application to UAVs, the FAA has chosen not to explicitly regulate certain other aircraft, such as model rockets, fireworks, and RC model aircraft. 14 CFR Part 101 specifically exempts smaller balloons, rockets and kites from the regulation and AC 91-57 addresses RC model airplanes, but is advisory only (see Appendix C). These systems are omitted from the regulations. All three U.S. Military Departments currently employ UAVs in the same size, weight, and performance regimes as those of RC models (e.g., Pointer/Raven for the Army and Air Force, and Dragon Eye for the Marine Corps). This plan calls for small UAVs similar to RC model aircraft (and operated similarly) (Cat I ROA) to be treated similarly to RC model aircraft.

These three cases provide informal divisions, based on the existing regulatory FAA infrastructure, into which all current military UAVs can be placed and are depicted with example UAV types in Figure 3-1. (also see Section 6.2).



\* Only “Part 91 aircraft” are certified airworthy and require licensed pilots

**Figure 3-1: ROA Divisions Based on FAA Definitions**

1. The regime that operates under Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) according to well-established regulations and procedures, as closely as possible to a manned aircraft.
2. The regime where Visual Meteorological Conditions (VMC) operations in the absence of ATC are similar to Restricted Category Aircraft operations.
3. The regime where VFR line-of-sight operations in uncontrolled airspace resemble model aircraft operations.

The above breakout is based on discussions with HQ FAA General Counsel during the course of the ongoing joint OSD-FAA Airspace Integration Initiative. It is anchored in existing FAA regulations rather than vendor-specific nomenclature or “marketing hype.” Under the above three divisions, the existing three FAA breakouts of class (rotorcraft, glider, balloon, etc.) used for right-of-way rules, category (transport, utility, acrobatic, etc.), and type (DC-3, B707, etc.), each described in the previous Section, can then be used to distinguish items such as licensing a Global Hawk operator who types on a keyboard from a UCAV operator who is required to control multiple vehicles.



### 3.2 Airworthiness Certification

The FAA's airworthiness regulations are meant to ensure that aircraft are built and maintained so as to minimize their hazard to aircrew, passengers, and people and property on the ground. Airworthiness is concerned with the material and construction integrity of the individual aircraft and the prevention of it coming apart in mid-air and/or causing damage to persons or property on the ground.

FAA regulations do not require "public aircraft" (ones government-owned or operated) to be certified airworthy to FAA standards. Because most non-military public aircraft are versions of aircraft previously certified for commercial or private use, however, the only public aircraft *not* related to FAA certification standards in some way are almost always military aircraft, as shown in Table 3-1. Instead, these aircraft are certified through the military's internal airworthiness certification/flight release processes.

**Table 3-1: FAA Involvement in Air Force Aircraft Certification<sup>4</sup>**

<b>Example Aircraft: C-9, C-20, VC-25, C-32, C-37, C-40</b>	<b>Example Aircraft: E-3, E-4, E-8, KC-10, Airborne Laser</b>	<b>Example Aircraft: F-117, F-15, F-16, F/A-22, B-1, B-2, many others</b>
FAA certified type design maintained throughout service life	Basic airplane FAA type certified	No FAA certification involvement
FAA provides airworthiness, test, engineering, and production staff to certify aircraft design	Modifications more extensive than FAA willing to certify	Air Force responsible for all airworthiness verification and certification activities
Air Force responsible for airworthiness certification	Air Force responsible for qualification of all non-FAA certified modifications and airworthiness	

Military UAVs are following the well established airworthiness certification processes. The Air Force requirement is defined in Air Force Policy Directive (AFPD) 62-6. As shown in Table 3-2 below, the weapon system's Single Manager is the airworthiness certifying official (AFPD 62-6). The chief engineer and Defense Contract Management Agency (DCMA) are the compliance agents. The Single Manager also makes and documents a positive determination of safety prior to the first flight of new aircraft. The policy also establishes the Airworthiness Certification Criteria Control Board. The board is chaired by the Commander, Aeronautical Systems Center, who is the final approving authority for the airworthiness certification criteria. This policy also

<sup>4</sup> Source: USAF Airworthiness Certification brief, September 2004. POC: Jim Warren, ASC/ENSI.

reinforces the requirement that all aircraft modifications require prior approval from the Single Manager. AFPD 62-6 also applies to commercial derivative aircraft. Compliance with FAA type certification requirements, however, takes precedence over Air Force airworthiness certification criteria whenever possible. The Navy, Army, and Marine Corps have similar processes. A Tri-Service memorandum of agreement describes the responsibilities and actions associated with mutual acceptance of airworthiness certifications for manned and unmanned aircraft systems within the same certified design configuration, envelope, parameters, and usage limits certified by the originating Service.

**Table 3-2: Civil and Public Parallels in Certification<sup>5</sup>**

	<b>Civil (14 CFR) Process</b>	<b>Public (OSS&amp;E) Process</b>
<b>Customer</b>	Airline	Major Command (MAJCOM)
<b>Certification Authority</b>	FAA	Single Manager
<b>Compliance Agent</b>	FAA or designee	Chief Engineer/DCMA
<b>Maintenance/ Operational Criteria</b>	14 CFR Parts 43, 91, 121, 135, 145	AFPD/AFI 11-2 & 21 series
<b>Certification Criteria</b>	14 CFR Parts 23, 25, 33	Airworthiness Certification Criteria (MIL-HDBK-516A)

Similar to manned military aircraft, unmanned military aircraft will also be subject to the airworthiness certification/flight release process (the Global Hawk is currently undergoing this process). The operational requirements for ROA operations in civil airspace means flight over populated areas must not raise airworthiness concerns; therefore, ROA standards cannot vary widely from those for manned aircraft without raising public and regulatory concern.<sup>6</sup>

### **3.3 Crew Qualification**

The FAA's qualification standards (14 CFR Parts 61, 63, 65, and 67) are meant to ensure the competency of aircrew and aircraft maintainers. As in the case of airworthiness certification, these Parts do not pertain to military personnel who are certified in a similar, parallel process. DoD and FAA have signed a memorandum of agreement through which DoD agrees to meet or exceed civil training standards, and the FAA agrees to accept military rated pilots into the NAS. These factors indicate a certain minimum knowledge standard is required of all pilots-in-command in order to operate aircraft in the NAS.

*Each Service identifies what and how it will operate and create the training programs necessary to safely accomplish the missions.* Some of the UAV-related training is a fundamental shift away from the skills needed to fly a manned aircraft (e.g., ground-based visual landing). These differences can relate to the means of landing:

<sup>5</sup> Source: USAF Airworthiness Certification brief, November 2003. POC: Jim Warren, ASC/ENSI.

<sup>6</sup> While this will also be true for any future unmanned public aircraft, certification of non-public UAVs remains an open issue for commercial or private UAV builders and operators.

visual remote, aided visual, or fully autonomous. They may also relate to different interface designs for the UAV functions, or the level of control needed to exercise authority over a vehicle based on its autonomous capability. As a result, the Services will have minimum standards for knowledge skills required of UAV operators operating in the NAS; this minimum standard may differ for given classes of ROAs/UAVs. ROA operators<sup>7</sup> will be expected to conform to these requirements.

Another issue that arises is when civilian pilots, such as those working for an aircraft manufacturer building UAVs for the military, need to fly their company's product during the performance of a military contract, such as for test, production delivery, and acceptance (DD Form 250) flights. The Defense Contract Management Agency (DCMA), who is responsible for such activities leading up to the acceptance of aircraft by the government, has established a policy letter (DCMA Instruction 8210.1, dated 13 November 2002) requiring all contractor UAV operators to hold a current FAA Private or Commercial Pilot and Instrument rating to fly outside of restricted or warning areas. This policy has already been waived in certain conditions when the operator training and currency requirements have been found adequate for the operation. Qualification standards for non-military UAV operators and maintainers will eventually need an FAA rating that reflects the type of vehicle they are operating. Excerpts of this document are provided in Appendix D.

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<sup>7</sup> *NOTE:* UAV operators may, or may not, be "rated pilots". For this Airspace Integration Plan, "operator" is the generic term to describe the individual with the appropriate training and Service certification for the type of UAV being operated, and as such, is responsible for the air vehicle's operations and safety.



## 4.0 Technology Issues

When discussing UAV technology, it is important to first address the notion that replacing a human pilot with technology increases the risk involved. This pejorative perception that UAVs are, by nature, more dangerous than manned aircraft can be mitigated by recognizing that UAVs possess the following inherent advantages over manned aircraft that contribute to flying safety.

- Many manned aircraft mishaps occur during the take-off and landing phases of flight, when human decisions and control inputs are substantial factors. Robotic aircraft are not programmed to take chances; either preprogrammed conditions are met to land, or the system goes around.
- Since human support systems are not carried, mishaps from failed life support systems (oxygen, pressure, temperature, etc.) will not occur.
- Smoke from malfunctioning, but non-vital, onboard systems does not pose the same threat of loss. Smoke in the cockpit of a manned aircraft can distract operators and lead to obscured vision or breathing difficulties.
- Automated take-offs and landings eliminate the need for pattern work, resulting in reduced exposure to mishaps, particularly in the area surrounding main operating bases.

The preceding points are useful to keep in mind when considering the various technology issues surrounding ROA airspace integration. It is also important to remember that 14 CFR Part 91 does not directly prohibit military UAVs from flying as long as they can comply with existing regulations. This makes such compliance a technical rather than a regulatory issue.

### 4.1 *See-and-Avoid*

A key requirement for routine access to the NAS is ROA compliance with 14 CFR 91.113, “Right-of-Way Rules: Except Water Operations.” This is the section that contains the phrase “see-and-avoid,” and is the primary restriction to normal operations of UAVs. The intent of “see-and-avoid” is for pilots to use their sensors (eyes) and other tools to find and maintain situational awareness of other traffic and to yield the right-of-way, in accordance with the rules, when there is a traffic conflict. Since the purpose of this regulation is to avoid mid-air collisions, this should be the focus of technological efforts to address the issue as it relates to UAVs rather than trying to mimic and/or duplicate human vision. In June 2003, USAF’s Air Combat Command (ACC) sponsored a joint working group to establish and quantify a sense-and-avoid (S&A) system capability for submission to the FAA; their White Paper, Sense-and-Avoid Requirement for Remotely Operated Aircraft, was released in June 2004.

Relying simply on human vision results in mid-air accounting for an average of 0.8 percent of all mishaps and 2.4 percent of all aviation fatalities incurred annually (based on the 3-year average from 1998 to 2000).<sup>8</sup> Meaningful sense-and-avoid performance must alert the operator to local air traffic at ranges sufficient for reaction time and avoidance actions by safe margins. Furthermore, UAV operations beyond Line-of-Sight (LOS) may require an automated S&A system due to potential communications latencies or failures.

The FAA does not provide a quantitative definition of see-and-avoid, largely due to the number of combinations of pilot vision, collision vectors, sky background, and aircraft paint schemes involved in seeing oncoming traffic. Having a sufficient field of regard (FOR) for a UAV S&A system, however, is fundamental to meeting the goal of assured air traffic separation. The FAA does provide a cockpit field of regard recommendation in its Advisory Circular 25.773-1 (see Appendix E), but the purpose of AC 25.773-1 does not specifically mention see-and-avoid.

Although an elusive issue, one fact is apparent. The challenge with the S&A issue is based on a capability constraint, not a regulatory one. Given the discussions in this and previous Sections, a possible definition for S&A systems emerges: sense-and-avoid is the onboard, self-contained ability to

- Detect traffic that may be a conflict
- Evaluate flight paths
- Determine traffic right-of-way
- Maneuver well clear according to the rules in Part 91.113, or
- Maneuver as required in accordance with Part 91.111.

#### **4.1.1 Detection Requirements and Methods**

According to the right-of-way rules (14 CFR 91.113), any aircraft must detect traffic that might be a conflict (becomes less than 500 foot separation) and then yield if required. Based on analysis, this means it must yield to aircraft from about 10 degrees left of the nose (approximately head on) to 90 degrees right of the nose depending on class. Prudence suggests that the search volume should include 90 degrees left of the nose as well. NASA studies<sup>9</sup> have shown for climbing or descending traffic, plus or minus 15 degrees search in elevation will adequately scan for converging aircraft which are using as much as 20 degree angles of climb.

FAA Advisory Circular 25.773-1 describes the cockpit visibility requirements from a design standpoint. While it does not specifically address *where* a pilot should be

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<sup>8</sup> National Transportation Safety Board aviation statistics.

<sup>9</sup> NASA Environmental Research and Sensor Technology (ERAST) program analysis conducted in support of See-and-Avoid Flight testing, March 2002 and 2003.

looking, it does exclude those areas where a pilot is *not* expected to be looking. Another FAA document (P-8740-51) provides guidance for pilots on “How to Avoid a Mid-air Collision.” It suggests scanning methods, rates, and locations that will increase the probability of detecting a mid-air threat within the pilot’s field of regard. Finally, Advisory Circular 90-48C provides information on a pilot’s role in collision avoidance.

In the international community, ICAO has also set standards which offer yet more guidance on azimuth search areas. A summary of these detection requirements and others is provided in Table 4-1, and the technology available to search these defined regions is described in detail in the following sections.

**Table 4-1: Existing Guidance for Detection Search Areas**

Source	Azimuth	Elevation
FAA P-8740-51: How to Avoid a Mid-Air Collision	+/- 60 degrees	+/- 10 degrees
International Standards, Rules of the Air, Section 3.2 (ICAO)	+/- 110 degrees	No guidance
FAA Advisory Circular 25.773-1 (Transport Aircraft Design)	+/- 120 degrees	Variable: +37 and -25 degrees (varies with azimuth)

This suggests the following requirement for an S&A systems standard: *Sense-and-avoid systems should provide a minimum traffic detection capability of plus or minus 110 degrees in azimuth measured from the longitudinal axis and plus or minus 15 degrees in elevation from the cruise speed level line.* The 15 degree elevation value is based on independent NASA and OSD analysis to detect climbing or descending threats.<sup>9</sup>

#### 4.1.1.1 Range Requirement

In addition to the detection location relative to the ROA, the range of the potential collision threat must also be considered. The system will need to detect the aircraft in adequate time to process the information, determine the conflict, and execute the maneuver according to the right-of-way rules. DoD has conducted computer based simulations and analysis that confirm independent NASA findings<sup>10</sup> that the time needed to complete the avoidance maneuver depends primarily on the bank angle of the maneuver for speeds greater than about 80 knots. Because ROA will limit the angle of bank for preplanned maneuvers, the time required to perform the limited angle of bank maneuver is determined. Any additional time necessary for processing and/or operator response can be added to the maneuver time to determine the total time necessary to detect the traffic prior to collision.

<sup>10</sup> OSD-FAA MARCAT and NASA ERAST program studies.



Once this total time required is determined, the range is calculated dependent on the ROA's velocity and a representative traffic closing velocity vector. For example, traffic below 10,000 feet is generally limited to 250 knots indicated, while higher traffic might travel at 0.9 Mach. The range required of the detection system is then a function of the maneuverability and velocity of the ROA and its operational traffic. The Air Combat Command-sponsored joint working group mentioned above, using the terminology remotely operated aircraft, has proposed that:

*The sense-and-avoid system must detect the traffic in time to process the sensor information, determine if a conflict exists, and execute a maneuver according to the right-of-way rules. If pilot interaction with the system is required, transmission and decision time must also be included in the total time between initial detection and the point of minimum separation.<sup>11</sup>*

#### **4.1.1.2 Sensor Requirement**

The system will need to detect traffic conflicts whether they are cooperative or non-cooperative. A cooperative system relies on transmissions from the other aircraft to develop situational awareness. Detection can be further subdivided into passive or active techniques applicable in cooperative or non-cooperative traffic environments.

##### **4.1.1.2.1 Active, cooperative**

The **active, cooperative** scenario involves an interrogator monitoring a sector ahead of the ROA to detect oncoming traffic by interrogating the transponder on the other aircraft. Its advantages are that it provides both range and bearing to the traffic and can function in both visual and instrument meteorological conditions (VMC and IMC). Its disadvantages are its relative cost. Current systems available in this category include the various Traffic-alert and Collision Avoidance Systems (TCAS).

##### **4.1.1.2.2 Active, non-cooperative**

The **active, non-cooperative** scenario relies on a radar- or laser-like sensor scanning a sector ahead of the ROA to detect all traffic, whether transponder-equipped or not. The returned signal provides range, bearing, and closure rate, allowing prioritization of oncoming traffic for avoidance, in either VMC or IMC. Its potential drawbacks are its relative cost, the bandwidth requirement to route its imagery (for non-autonomous systems), and its weight. An example of an active, non-cooperative system that is currently available is a combined microwave radar and infrared sensor originally developed to enable helicopters to avoid power lines.

##### **4.1.1.2.3 Passive, cooperative**

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<sup>11</sup> *Sense-and-Avoid Requirement for Remotely Operated Aircraft (ROA)*, 25 June 2004, HQ ACC/DR-UAV SMO.

The **passive cooperative** scenario, like the active cooperative one, relies on everyone having a transponder, but with everyone's transponder broadcasting position, altitude and velocity data. Its advantages are its lower relative cost (no onboard interrogator required to activate transponders) and its ability to provide S&A information in both VMC and IMC. Its disadvantage is its dependence on all traffic carrying and continuously operating transponders. In this scenario, ROA should have the capability to change transponder settings while in flight.

#### 4.1.1.2.4 *Passive, non-cooperative*

The **passive non-cooperative** scenario is the most demanding one. It is also the most analogous to the human eye. An S&A system in this scenario relies on a sensor to detect and provide azimuth and elevation to the oncoming traffic. Its advantages are its moderate relative cost and ability to detect non-transponder equipped traffic. Its disadvantages are its lack of direct range or closure rate information, potentially high bandwidth requirement (if not autonomous), and its probable inability to penetrate weather. The gimbaled EO/IR sensors currently carried by reconnaissance UAVs are examples of such systems, but if they are looking at the ground for reconnaissance then they are not available to perform S&A. An emerging approach that would negate the high bandwidth requirement of any active system is optical flow technology, which reports only when it detects an object showing a lack of movement against the sky, instead of sending a continuous video stream to the ground controller. Imagery from one or more inexpensive optical sensors on the UAV is continuously compared to the last image by an onboard processor to detect minute changes in pixels, indicating traffic of potential interest. Only when such objects are detected is their bearing relayed to the ground.

#### 4.1.1.3 Comparison of Detection Technologies

Figure 4-1 summarizes the sensor detection trade space.

		Oncoming Traffic is...	
		Cooperative	Non-Cooperative
Onboard Systems are...	Active	<b>Pro:</b> <ul style="list-style-type: none"> <li>- Both range and bearing provided</li> <li>- Functions in VMC and IMC</li> </ul> <b>Con:</b> <ul style="list-style-type: none"> <li>- SWAP</li> <li>- Cost</li> </ul> <p>Example: TCAS systems</p>	<b>Pro:</b> <ul style="list-style-type: none"> <li>- Range, bearing, and closure rate provided</li> <li>- Functions in VMC and IMC</li> </ul> <b>Con:</b> <ul style="list-style-type: none"> <li>- Data link required</li> <li>- SWAP</li> <li>- Cost</li> </ul> <p>Example: radars</p>
	Passive	<b>Pro:</b> <ul style="list-style-type: none"> <li>- Cost</li> </ul> <b>Con:</b> <ul style="list-style-type: none"> <li>- VMC only</li> </ul> <p>Example: High Visibility Paint</p>	<b>Pro:</b> <ul style="list-style-type: none"> <li>- Cost</li> <li>- Detects non-transponder (all) aircraft</li> </ul> <b>Con:</b> <ul style="list-style-type: none"> <li>- Bearing only provided</li> <li>- Data link required</li> <li>- VMC only</li> </ul> <p>Example: EO/IR sensors</p>

## **Figure 4-1: Detection Technology Trade space**

### **4.1.2 Avoidance Requirements and Methods**

Once the "sense" portion of S&A is satisfied, the UAV must use this information to execute an avoidance maneuver. The latency between seeing and avoiding for the pilot of a manned aircraft ranges from 10 to 12.5 seconds according to FAA and DoD studies<sup>12</sup>. If relying on a ground operator to see and avoid, the UAV incurs the same human latency, but adds the latency of the data link bringing the image to the ground for a decision and the avoidance command back to the ROA. This added latency can range from less than a second for line-of-sight links to more for satellite links.

#### **4.1.2.1 Pilot-in-the-loop**

Current UAVs are flown with varying degrees of human control and/or oversight. When flying in the NAS, this oversight must adhere to the requirements of 14 CFR Part 91 and its intent for pilots to see and avoid other aircraft. For reference, the regulations, including right-of-way rules for pilots, are provided below. These regulations apply to all aircraft (civil and public).

##### **§91.111 Operating near other aircraft.**

- (a) No person may operate an aircraft so close to another aircraft as to create a collision hazard.
- (b) No person may operate an aircraft in formation flight except by arrangement with the pilot in command of each aircraft in the formation.
- (c) No person may operate an aircraft, carrying passengers for hire, in formation flight.

##### **§91.113 Right-of-way rules: Except water operations.**

- (a) Inapplicability. This section does not apply to the operation of an aircraft on water.
- (b) General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

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<sup>12</sup> Tyndall Air Force Base Mid-Air Collision Avoidance Study; FAA P-8740-51; see also Krause, Avoiding Mid-Air Collisions, p. 13

(c) In distress. An aircraft in distress has the right-of-way over all other air traffic.

(d) Converging. When aircraft of the same category are converging at approximately the same altitude (except head-on, or nearly so), the aircraft to the other's right has the right-of-way. If the aircraft are of different categories --

(1) A balloon has the right-of-way over any other category of aircraft;

(2) A glider has the right-of-way over an airship, airplane, or rotorcraft; and

(3) An airship has the right-of-way over an airplane or rotorcraft.

However, an aircraft towing or refueling other aircraft has the right-of-way over all other engine-driven aircraft.

(e) Approaching head-on. When aircraft are approaching each other head-on, or nearly so, each pilot of each aircraft shall alter course to the right.

(f) Overtaking. Each aircraft that is being overtaken has the right-of-way and each pilot of an overtaking aircraft shall alter course to the right to pass well clear.

(g) Landing. Aircraft, while on final approach to land or while landing, have the right-of-way over other aircraft in flight or operating on the surface, except that they shall not take advantage of this rule to force an aircraft off the runway surface which has already landed and is attempting to make way for an aircraft on final approach. When two or more aircraft are approaching an airport for the purpose of landing, the aircraft at the lower altitude has the right-of-way, but it shall not take advantage of this rule to cut in front of another which is on final approach to land or to overtake that aircraft.

Section 91.111(a) makes it clear that the intent of this statutory language is to ensure that operators avoid creating “a collision hazard.” Section 91.113 provides the right-of-way rules to clarify which aircraft should yield. In order of decreasing priority, right-of-way is granted to vehicles 1) in distress, 2) landing, 3) a balloon, 4) a glider, 5) an airship, 6) towing or air-air refueling, 7) on the right-hand, 8) in-front, and 9) below.

From “How To Avoid A Midair Collision” (FAA document P-8740-51), “Collision avoidance involves much more than proper eyeball techniques. You can be the most conscientious scanner in the world and still have an in-flight collision if you neglect other important factors in the overall see-and-avoid picture.” The document describes a “see-and-avoid checklist” that includes proper procedures on the ground (e.g., flight planning, adding high-visibility features to the aircraft, etc.) to good en-route practices (e.g., avoiding crowded airspace, using radios effectively, etc.).

#### **4.1.2.2 Autonomous**

The pilot-in-the-loop scenario is one possible way to recognize an impending collision and initiate the required resolution maneuver. For beyond line-of-sight ROA operations, however, other methods to initiate action are required. The sense-and-avoid system or an acceptable alternative must be developed and must work throughout all

phases of flight. In the case of ROA, where the operator and crew are off-board and connected via a data-link, the sense-and-avoid system must work even if the data-link malfunctions.

An alternative is to empower the ROA to determine autonomously whether and which way to react to avoid a collision once it detects oncoming traffic, thereby removing the latency imposed by data links. This approach has been considered for implementation on TCAS II-equipped manned aircraft, since TCAS II already recommends a vertical direction to the pilot; but simulations have found the automated maneuver worsens the situation in a fraction of the scenarios. For this reason, the FAA has not certified automated collision avoidance algorithms based on TCAS resolution advisories; doing so would set a significant precedent for ROA S&A capabilities. Autonomy is discussed in more detail in Section 4.2.

### **4.1.3 Equivalent Level of Safety**

The planned introduction of ROA into the airspace presents unique challenges with respect to piloted and remotely operated aircraft safety, flight operations, design requirements, and cost. When pursuing a definition for Equivalent Level of Safety (ELOS), the primary goal for the ROA is matching the safety provided by the manned collision avoidance system *as a whole*, not just the performance of the human eye. This idea can be developed using an empirical approach. One such approach is outlined below.

The circumstances in which manned aircraft experience mid-air (MAC) or near mid-air collisions (NMAC) help define the ELOS requirement for unmanned aviation. Historically, based on National Transportation Safety Board (NTSB) statistics, the majority of mid-air collisions occur

- Between two general aviation aircraft
- In VFR conditions
- During daytime conditions
- With a Certified Flight Instructor (CFI) onboard
- Within the traffic pattern (80% of these on final approach)
- Below 3,000' AGL
- Within 10 miles of an untowered airport

These facts indicate the most significant mid-air collision risk occurs at the lower end of the aviation spectrum where low-flying, inexperienced (i.e., student) pilots fly without the aid of air traffic control. As a result, if ELOS is “sized” for this region of general aviation, ROA sense-and-avoid system reliability requirements could be established that would be equal to or better than a manned aircraft’s level of safety with respect to mid-air collisions for this operating environment.

The *see-and-avoid system infrastructure* for a manned aircraft is the pilot, crew, sensors, and beacons onboard the aircraft, coupled with the air traffic control infrastructure in-place on the ground (and in orbit) designed to support them and their operation in the airspace. The critical failure rate of this system is known; it is the rate of mid-air collisions per year. Table 4-2 provides the 10-year statistics for this rate.

**Table 4-2: General Aviation Mid-air Collision History<sup>13</sup>**

Year	MAC Events	Operating Hours (millions)	Rate per 10 <sup>6</sup> Flight Hours
1991	18	27.2	0.66
1992	11	24.8	0.44
1993	13	22.8	0.57
1994	11	22.2	0.50
1995	14	24.9	0.56
1996	18	24.9	0.72
1997	13	25.5	0.51
1998	14	26.8	0.52
1999	15	29.5	0.51
2000	19	30.8	0.62
2001	5	25.9	0.19
2002	7	25.9	0.27
Average	13.17	25.93	0.51

These data indicate that the average manned see-and-avoid system failure rate is .51 per million flight hours. It is important to note that this value does not include the near mid-air collisions (NMAC), both reported and unreported, which result from the systems' failures. For example, there were 209 reported NMAC in 2001.<sup>14</sup> While there is no way to determine the number of unreported and/or unidentified NMACs, estimates put the number at 10 to 100 times the MAC rate.

By combining the average mid-air collision rate of 0.51 with the reported NMAC of 209 in 2001, it can be estimated that the probability of a MAC or a NMAC for a manned general aviation aircraft is  $8.57 \times 10^{-6}$  per flight hour. *This is the failure rate of the manned see-and-avoid system infrastructure.* If following the FAA precept of ELOS, it is also the failure rate required for unmanned aviation sense-and-avoid system operating in this airspace. *As an example,* the required reliability for the unmanned sense-and-avoid system would be .9999786, or five 9's, if assuming a constant hazard function (i.e., a mature system) operating during an average 2.5 hour flight. This is the overall reliability, which includes the sensor's probability of detection, various subsystem availability and reliability, and latencies in communications or pilot-in-the-loop reaction times.

The consequence of exceeding this rate is that the ROA sense-and-avoid system would then be failing more frequently than the manned system, and would therefore not be equivalent to it. While it is likely that very few of these ROA S&A system failures

<sup>13</sup> Source: Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation

<sup>14</sup> Source: FAA Administrator's Factbook, May 2002, ATX-400.

would result in mid-air collisions, neither do all failures of the manned see-and avoid system infrastructure. These *near* mid-air collisions occur not just from a failure of eyesight (i.e. the human sensor), but also from inadequate scanning, inattentive piloting, obscuration of the FOR by the aircraft structure, etc. The five 9's value also includes operating procedures and environments. If unmanned aviation avoids certain higher risk environments (i.e., not flying at untowered airports) or follows certain risk mitigating procedures, the requirements on the sensor hardware may be further reduced.

This definition for required reliability has several advantages. First, it is based on FAA and National Transportation Safety Board statistics. Second, it follows the OSD-FAA effort precept "conform rather than create" as discussed in Section 1.4. It does not challenge current manned see-and-avoid standards, but does establish that sense-and-avoid is a technical vice regulatory constraint to unmanned aviation. Finally, it allows designers the flexibility to tailor their sense-and-avoid sensors to their specific ROA. Smaller UAVs, which fly lower, within line-of-sight, and/or in less congested airspace, would not necessarily be required to carry the same sensor as their larger counterparts flying in a different airspace environment.

Following from this analysis are several recommendations intended to facilitate efforts focused on addressing the sense-and-avoid issue.

- ROA sense-and-avoid systems should ensure an overall failure rate of no more than .51 per million flight hours. (This equivalence value does not incorporate statistics for NMAC of manned aircraft or other operating environments.)
- Equivalence can be achieved through high component reliability/performance of the S&A system, specific risk-mitigating operating procedures and environments for the S&A platform, or a combination of both.
- Systems achieving this reliability should be deemed equivalent to manned aircraft levels of safety for see-and-avoid requirements.

The above proposals can be leveraged for consensus-based standards development, which could ultimately determine the design and performance standards for a collision avoidance system.

## **4.2 Command, Control, Communications**

### **4.2.1 Data Link Security**

In general, there are two main areas of concern when considering link security: inadvertent or hostile interference of the uplink and downlink. The forward ("up") link controls the activities of the platform itself and the payload hardware. This command and control link requires a sufficient degree of security to ensure that only authorized agents have access to the control mechanisms of the platform; this is an imperative for flights in the NAS given the events of September 11, 2001. The return ("down") link transmits critical data from the platform payload to the warfighter or analyst on the



ground or in the air. System health and status information must also be delivered to the ground control station or UAV operator without compromise.

Future UAV systems are to be integrated into the DoD Global Information Grid (GIG) architecture. Without high assurance of the confidentiality and security of UAV data links, the GIG cannot be fully trusted to ensure that information is not disclosed to, or corrupted by, unauthorized entities, processes, or devices. This confidence is critical to provide an adequate level of protection and isolation for not only UAVs, but also the multiple user traffic streams that will share this common transport backbone.

All classified user information in transit must be protected with National Security Agency (NSA) approved Type-1 cryptography. Additionally, unclassified information in transit must be protected with National Institute of Standards & Technology (NIST) approved Type-2 cryptography. Use of packet-based encryption of classified user information will require additional protection in high-risk environments in order to mask the details of the underlying packet stream (i.e. packet headers, packet lengths, packet volume, packet timing). The following encryption requirements for confidentiality are specified for the GIG.

- Type-1 cryptographic security mechanisms for all classified user information, metadata, network control, and network management information.
- At a minimum, NIST/NSA approved cryptographic security mechanisms for all unclassified user information, metadata, network control, and network management information.
- Type-1 or other NSA approved packet masking (i.e. link encryption cover) availability security mechanisms for all RF links and high-risk communications medium.

All data links should be designed in accordance with the current High Assurance Internet Protocol Interoperability Specification (HAIPIS) to accommodate High Assurance Internet Protocol Encryption (HAiPE) devices.

#### **4.2.2 Redundant/Independent Navigation Capabilities**

The air navigation environment is changing, in part, because of the demands of increased traffic flow. Allowances for deviation from intended flight paths are being reduced. This provides another means for increasing air traffic capacity as airways and standard departures and approaches can be constructed with less separation. As tolerances for navigational deviation decrease, the need to precisely maintain course grows. All aircraft must ensure they have robust navigational means. Historically, this robustness has been achieved by installation of redundant navigational systems. The need for dependable, precise navigation reinforced the redundancy requirements.

While navigation accuracy and reliability pertain to military operations and traffic management, current systems are achieving the necessary standard without redundancy,

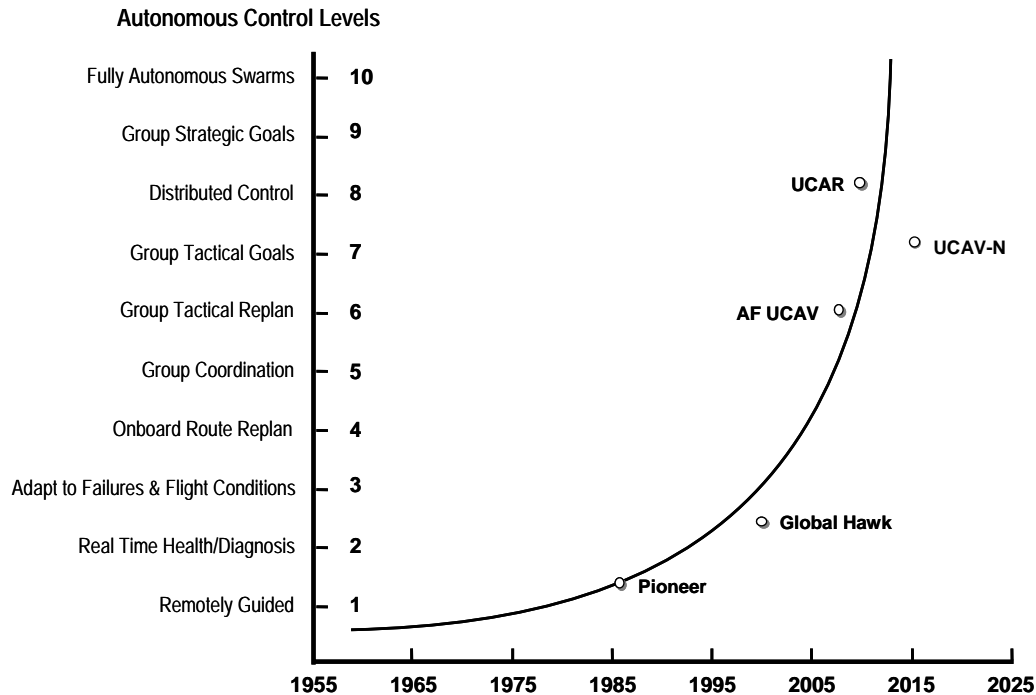
and without reliance on ground based navigation aids. The *Federal Radionavigation Plan*, signed March 2002, establishes the following national policies:

- Unaugmented, properly certified GPS is approved as a primary system for use in oceanic and remote airspace.
- Properly certified GPS is approved as a supplemental system for domestic en route and terminal navigation, and for non-precision approach and landing operations.
- The FAA's phase-down plan for ground-based NAVAIDS retains at least a minimum operational network of ground-based NAVAIDS for the foreseeable future.
- Sufficient ground-based NAVAIDS will be maintained to provide the FAA and the airspace users with a safe recovery and sustained operations capability in the event of a disruption in satellite navigation service.

These policies apply, as a minimum, to all aircraft flying in civil airspace. With GPS, the prospect for relief of some redundancy requirements in manned aviation may be an option in the future. However, UAVs have a diminished prospect for relief since, unlike manned aircraft, a UAV cannot readily fallback on dead reckoning, contact navigation, and map reading in the same sense that a manned aircraft can.

### **4.2.3 Autonomy**

Advances in computer and communications technologies have enabled the development of autonomous unmanned systems. With the increase in computational power available, developmental UAVs are able to achieve much more sophisticated subsystem, guidance, navigation and control, sensor and communications autonomy than previous systems. Global Hawk is capable of Level 2-3 autonomy today (see Figure 4-2 below). Its airborne systems are designed to identify, isolate, and compensate for a wide range of possible system / sub-system failures and autonomously take actions to ensure system safety. Preprogrammed decision trees are built to address each possible failure during each part of the mission.



**Figure 4-2: Air Force Research Lab (AFRL)-Defined Levels of UAV Autonomy**

The Joint Unmanned Combat Air System (J-UCAS) program is extending the work being accomplished by previous UAV programs, advancing the state-of-the-art in multi-vehicle cooperation. Autonomy in this context applies to cooperative actions among the Unmanned Combat Aerial Vehicles (UCAV). They are envisioned to fly alone or as a forward element of a manned/unmanned mission. The UCAVs will have inter-vehicle data links to allow transfer of information between the UCAVs and between the UCAVs and the manned vehicles. The information may include mission plan updates, target designation information, image chips, and other sensor data. Key mission decisions will be made based on the information passed between the systems. As originally planned, the Air Force UCAV is to demonstrate Level 6 autonomy while the Navy UCAV is to demonstrate at least Level 7. The Unmanned Combat Armed Rotorcraft (UCAR) is to demonstrate Level 7 to 9.

One of the most difficult aspects of this level of autonomy is ensuring that all elements remain synchronized. Verifying that 1) all messages are received, 2) all vehicles have correctly interpreted the messages, and 3) the entire squadron has a single set of mission plans to execute will be a key accomplishment. Once developed, such reliable, highly autonomous UAV systems will facilitate integration into the FAA's Joint Air Traffic Management Vision (Section 6.1).

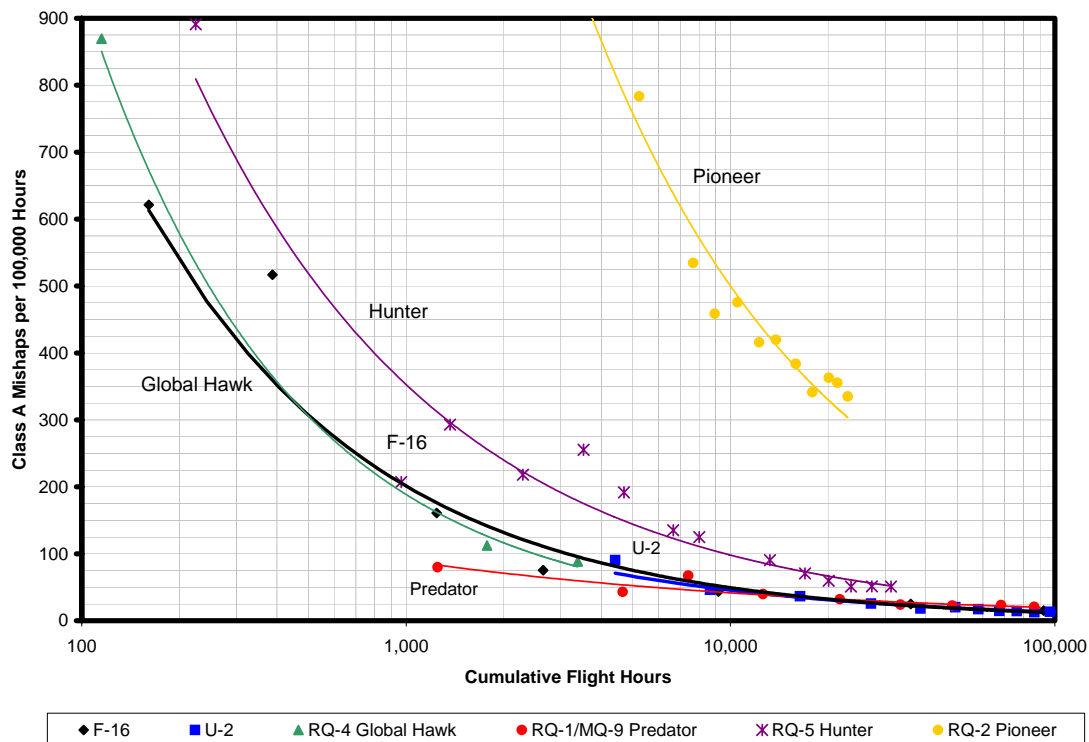
#### **4.2.4 Lost Link/ATC Communications**

In the event of lost command and control, military UAVs are typically programmed to climb to a pre-defined altitude to attempt to reestablish contact. If contact is not reestablished in a given time, the UAV can be pre-programmed to 1) retrace its outbound route home, 2) fly direct to home, or 3) continue its mission. With respect to lost communications between the ground control stations and the UAV, or the UAV and ATC, however, there is no procedure for a communications-out recovery. Examination of a lost link scenario illustrates that this communications issue can become a critical UAV failure mode, if left unaddressed.

NORDO (No Radio) requirements are well documented in 14 CFR 91.185. Remarkably, most lost link situations bear a striking resemblance to NORDO, and UAVs would enhance their predictability by autonomously following the guidance. The one exception to this case is the VFR conditions clause. UAVs, even with an adequate sense-and-avoid system (autonomous), would enhance overall safety by continuing to fly IFR. Should normal ATC-voice communications fail, the FAA also has the capability to patch airspace users through to the controlling ATC authority by phone at any time.

### **4.3 Reliability**

After sense-and-avoid, UAV reliability is arguably the largest hurdle in airspace considerations because it underlies UAV acceptance into civil airspace—whether domestic, international, or foreign. According to the *OSD UAV Reliability Study*, February 2003, today's UAVs suffer mishaps at one to two orders of magnitude greater than the rate per 100,000 hours incurred by manned military aircraft (see Figure 4-3). Improving reliability is necessary for winning the confidence of the general public, the acceptance of other aviation constituencies (airlines, general aviation, business aviation, etc.) and the willingness of the FAA to accept ROA flight. Acceptance of ROA operations by the FAA also should lead to acceptance by international (ICAO) and foreign civil aviation authorities of ROA operations. Such acceptance will greatly facilitate obtaining overflight and landing privileges when the U.S. military's larger, endurance UAVs deploy in support of contingencies. In addition, acceptance will save time and resources within both the DoD and the FAA by providing one standardized, rapid process for granting flight clearances. Finally, acceptance will encourage the use of UAVs in civil and commercial applications, resulting in potentially lower acquisition costs to military UAV procurement programs.



**Figure 4-3: US Military Aircraft and UAV Mishap Rates, 1986-2001**

Based on these trends shown in Figure 4-3, the *OSD UAV Roadmap, 2002-2027* set the following reliability-specific goal: Decrease the annual mishap rate of larger model UAVs (Cat III ROA) to less than 20 per 100,000 flight hours by FY09 and less than 15 per 100,000 flight hours by FY15.

Figure 4-3 also provides insight into aircraft reliability trends early in their life-cycle, showing great similarity between the mishap rates of manned military aircraft as they are introduced into service and that of today's UAVs. OSD's *UAV Reliability Study* provides more detail on this subject, as well as data describing common failure modes and potential reliability-enhancing technologies for military UAVs.

## 5.0 Airspace Integration Initiatives

This section highlights the major efforts that directly or indirectly facilitate ROA airspace integration. The on-going objective of OSD and its Airspace Integration Plan is to leverage each of these initiatives' products and/or lessons learned while ensuring that

duplication of effort is minimized or completely eliminated. Where applicable, relationships between these efforts are introduced, to be detailed more fully in the context of the FAA's modernization efforts in Section 6.0.

## **5.1 Demonstration Efforts**

### **5.1.1 OSD-FAA**

Discussed throughout this plan, the joint OSD-FAA Airspace Integration Initiative is intended to facilitate military UAV operations within the National Airspace System. The effort, begun in 2001 and planned to continue through 2005, has three focus areas.

- Technical Phase: Sense-and-avoid Requirements Quantification including Equivalent Level of Safety Investigations
- Regulatory Phase: File and Fly Procedures for ROA Operations
- Implementation Phase: File and Fly Demonstration around the country with an ROA equipped with a sense-and-avoid sensor system

#### **5.1.1.1 Technical Phase**

This phase focuses on resolving technology issues impeding routine ROA access to the NAS. Key among these issues is a sense-and-avoid capability in the absence of an onboard human pilot. It is an important note that the solution to the sense-and-avoid problem is being approached from a technical vice a regulatory perspective; no change or waiver to the regulatory requirement is sought. Although see-and-avoid is not quantifiably defined in FAA or ICAO publications, certain documents<sup>15</sup> help circumscribe the requirements for such a capability. This phase is proceeding in parallel with the regulatory phase, and highlights of it are presented in Section 4.1 and 5.4.1 of this document.

#### **5.1.1.2 Regulatory Phase**

This phase focuses on 14 CFR and FAA Order 7610.4 issues pertaining to ROA access to the NAS on a file and fly basis. The guiding precepts for this phase, as noted earlier, are to 1) do no harm, i.e., impact the Services' right to self-certify aircraft and aircrew, 2) conform to existing regulations, rather than create new ones, and 3) establish precedents that will sustain their adoption by international aviation bodies. As an example, lost communications procedures for ROA, widely approached as a technology issue, is seen as a regulatory matter and one for which adequate regulation exists. The rules for manned aircraft suffering lost communications can be satisfied in an identical manner by ROA. This phase is proceeding in parallel with the technical phase.

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<sup>15</sup> FAA AC 25.773-1, FAA P-8740-51, FAA AC 90-48C, ICAO Rules of the Air, Section 3.2.2.4

### **5.1.1.3 Implementation Phase**

This phase is intended to demonstrate 1) the file and fly process put into place by the regulatory phase's efforts and 2) the sense-and-avoid capability from the technical phase. Using an autonomous S&A system, an ROA is to fly around the United States in daylight conditions under visual flight rules (VFR). The demonstration will involve taking off and landing in each of eight FAA regions in the contiguous U.S. by filing a DD175 flight plan (i.e., without using the COA process). Some preliminary activities for this phase were accomplished in FY2003, and an initial kick-off meeting occurred in January 2004. These early efforts focus on opening dialog with selected UAV users/vendors to discuss plans for the initial demonstration as well as explore candidate technologies for sense-and-avoid.

### **5.1.2 Access 5/UNITE**

The Access 5 effort is an initiative intended to improve NAS access for high-altitude UAVs. Detailed planning was complete in July 2003. It involves NASA, FAA, DoD, and six High Altitude/Endurance UAV companies (UNITE). The Access 5 timeline covers 5 years (2004-2008) and proposes a four-step approach to achieving airspace access for high-altitude and long-endurance non-military UAVs.

- Step 1: Fly on an experimental certificate in Special Use Airspace (SUA) to FL400+ (Class A) then routing.
- Step 2: Fly on an experimental certificate in SUA to FL180+ then routing.
- Step 3: File & Fly to/from ROA Airports above FL180+
- Step 4: Include Diversion and Emergency handling.

NASA funded Steps 1 and 2 in March 2004. The total cost is estimated at roughly \$350M, with \$103M programmed starting in FY04. The initiative will be conducted under a Joint Sponsored Research Agreement.

In addition to NASA, FAA, and DoD, the Department of Homeland Security is also expected to participate. The general approach is to develop and demonstrate concepts, technology, standards, procedures, proposed changes to policy and rules, and additional products that will reduce the cost to produce, certify, and operate UAVs for non-military applications. The UAV Planning Task Force in OUSD(AT&L) is coordinating DoD's involvement in Access 5 based on 1) potential benefit of Access 5 development to DoD programs, 2) opportunity for NASA to leverage DoD activities, and 3) reduced costs and improved access that will accrue from a broader commercial and public use of UAVs. NASA briefed the detailed plan to agency and industry principals on 30 July 2003.

## **5.2 Standards Development Efforts**

The developing needs of unmanned aviation require appropriate standards for functions and activities not yet covered. This will likely include both new standards and the revision of existing standards. The DoD/Services are working standards for military certification. The application of civil standards can also provide synergism in the interest and safety of unmanned aviation generally. DoD policy is to promote standardization of materiel, facilities, and engineering practices to improve military operational readiness, reduce total ownership costs, and reduce acquisition cycle time. It is also DoD policy to state requirements in performance terms, wherever practical, and to make maximum use of non-Government standards and commercial technologies, products, and practices. To pursue these policies, there is a single, integrated Defense Standardization Program<sup>16</sup> and a uniform series of specifications, standards, and related documents. Organizations, in addition to the DSP, with specific aerospace standards are:

- American Institute of Aeronautics and Astronautics (AIAA)
- American Society of Testing & Materials (ASTM)
- American Welding Society (AWS)
- Electronic Industries Alliance (EIA)
- Electrostatic Discharge Association (ESDA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Institute of Environmental Sciences and Technology (IEST)
- International Civil Aviation Organization (ICAO)
- International Organization for Standardization (ISO)
- National Institute of Standards and Technology (NIST) - National Standards
- The North Atlantic Treaty Organization Standards Agency (NSA)
- Occupational Safety & Health Administration (OSHA)
- RTCA (originally organized at the Radio Technical Commission for Aeronautics)
- Society of Automotive Engineers (SAE)

## **5.3 Airspace Management-Related Efforts**

### **5.3.1 GANS/CNS/ATM**

Civil aviation authorities (FAA and ICAO) are implementing major changes to the existing Air Traffic Control (ATC) and Air Traffic Management (ATM) systems. This evolution will mandate improvements or additions to onboard communication, navigation and surveillance (CNS) equipment. In order to guarantee access to national

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<sup>16</sup> The DSP is chartered by DoD Instruction 4120.24, *Defense Standardization Program (DSP)*, which implements 10 USC 2451 and 2452. The Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) is responsible for DSP policies. The instruction designates the Director of the Defense Logistics Agency (DLA) as the DoD Executive Agent for the DSP.



and international airspace, the DoD has instituted the Global Access Navigation Safety (GANS)/CNS/ATM program. The GANS/CNS/ATM program's objective is to ensure military aircraft are properly equipped to allow continued unrestricted access to the airspace systems.

Assurance of GANS/CNS/ATM Certifications delineates the process for communications, navigation, and surveillance upgrades. NAS and ICAO required upgrades will include:

- (i) Communications: 8.33 KHz VHF Radios, LOS Data Link
- (ii) Navigation: Basic RNAV, RNP-1, ILS FM Immunity
- (iii) Surveillance: RVSM, Mode S, ADS B

These upgrades will involve a variety of complex coordinated activities ranging from OSS&E of current GPS/INS configuration to the selection, installation, system integration, and OSS&E of an ADS-B suite. Others, such as ILS-FM immunity, may not apply to UAVs.

### **5.3.2 ADS-B**

Automatic Dependent Surveillance Broadcast (ADS-B) is a technology which allows aircraft to broadcast information such as identification, position, and altitude. This broadcast information may be received and processed by other aircraft or ground systems for use in improved situational awareness, conflict avoidance and airspace management. With the use of Global Positioning System (GPS) or other navigation systems as a source of position data, ADS-B has the capacity to greatly improve the efficiency and safety of the National Airspace System.

Air-to-Air Cockpit Display of Traffic Information (CDTI) is the basic technology which will enable the pilot to electronically "see and avoid" other aircraft in a largely passive mode. Each aircraft automatically broadcasts its position to all equipped aircraft in the surrounding area, and this information is visually depicted on a cockpit display. Independent of ground based radar, CDTI will greatly enhance a pilot's situational awareness and lead to safer and more efficient airspace operations. ADS-B techniques can also enhance traffic collision avoidance systems in the future.

ADS-B provides surveillance data to controllers or aircraft operations facilities on the ground. An aircraft in flight broadcasts its position, altitude, identification, and other pertinent information to ground stations that relay this data to air traffic control or aircraft operations facilities. This information is used to effectively establish surveillance in remote locations or extend or replace current surveillance capabilities. Air-to-Ground ADS-B can greatly assist controllers and aircraft operations facilities with airspace management.

ADS-B provides accurate position and identification of aircraft and other equipped vehicles for airport surface surveillance. Aircraft and vehicles broadcast information containing position, speed, heading and identification to ground stations

located around the airport. This information is relayed to air traffic controllers and airport management facilities personnel. Airport surface surveillance enhanced through the ADS-B data link application will lead to safer and more efficient airport surface operations in all weather conditions.

ADS-B results in reduced communication congestion, enhanced situational awareness and safety, autonomous air-to-air surveillance, position tracking, reduced taxi/take-off delays, and expanded surveillance. Its potential implementation on UAVs could alleviate many of the problems identified in this report and being worked by the various initiatives.

### **5.3.3 TCAS**

The Traffic Alert and Collision Avoidance System (TCAS) operates onboard aircraft to facilitate separation in the airspace. TCAS accomplishes this by detecting nearby aircraft that respond to Mode A, or Mode C and S interrogations by other TCAS-equipped aircraft. By cooperating, a TCAS system can track and evaluate potential collision threats. Displays of traffic information can be made available to the pilot, and resolution and/or traffic advisories are provided during likely mid-air collision situations.

The TCAS system, however, is not certified to be tied into aircraft (manned or unmanned) flight control systems (FCS). It is to be used in manned systems in an advisory role only. Such a system (if linked to the FCS of a UAV) could potentially provide inputs to the automated avoidance maneuver capability required for over-the-horizon UAV operations.

### **5.3.4 WAAS**

The FAA is developing the Wide Area Augmentation System (WAAS) to augment GPS, and this could subsequently affect UAV command and control. WAAS is designed primarily for aviation users. The WAAS provides a signal-in-space to enable WAAS users to navigate the en route through nonprecision approach phases of flight. The signal-in-space provides three services: (1) integrity data on GPS and Geostationary Earth Orbit (GEO) satellites, (2) differential corrections of GPS and GEO satellites to improve accuracy, and (3) a ranging capability to improve availability and continuity.

The FAA announced in August 2000 that WAAS is continuously broadcasting differential corrections and is available for non-safety applications. WAAS initial operational capability for safety applications (as a supplemental means of navigation), achieved in 2003, supports en route through approach with vertical guidance lateral/vertical navigation (LNAV/VNAV) operations. The long-term plans for navigation architecture are based on a WAAS primary means of navigation determination in 2009. These plans are being updated based on the current IOC schedule and the reports of the WAAS Independent Review Board and WAAS Integrity and Performance Panel (WIPP). The WIPP has recommended that after achieving IOC, the WAAS be incrementally improved to expand the area of coverage, increase the availability of nonprecision approaches and RNAV, increase signal redundancy, reduce operational restrictions, and support precision approach operations.

The recently published Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System also recommended that the FAA continue to upgrade the system's resistance to intentional and unintentional interference. To that end, as well as to improve performance, a key recommendation is to utilize the new GPS civil signal at L5 (1176.45 MHz), when it is available, to provide a more robust, interference-resistant, and available service to users equipped with L5 receivers. The result of these incremental improvements will enable aircraft equipped with WAAS avionics to execute all phases of flight in the NAS except Category II and III precision approaches.

The FAA plans to allow augmented GPS, or redundant GPS (TSO 129), to serve as a primary navigational aid in the National Airspace for domestic en route and terminal precision approaches.

## **5.4 Sense-and-Avoid Efforts**

### **5.4.1 OSD**

To address the above sense-and-avoid requirements, the Mid-Air Collision Assessment Tool (MARCAT) was developed under the joint OSD-FAA airspace effort. MARCAT is a software application that offers unique insight into the sense-and-avoid requirements associated with unmanned flight within the NAS. MARCAT, in combination with other analysis tools, is being used to quantify S&A parameters in the context of unmanned and manned flight operations (e.g., the effects of latencies, vehicle and/or human performance, regulatory requirements, etc.). MARCAT provides data on collision occurrences, analyzes near misses, evaluates possible resolution maneuvers, and enables visualization of the parameters to view the multi-variable problem more easily. The software generates this data by iterating through a comprehensive set of thousands of collision scenarios.

These analyses are being used to help quantify the risk of UAV operations in the National Airspace. The results have indicated that matching the performance of the human pilot in many cases is not adequate. Specifically, the nominal human detection range of 1.5 to 2.0 nautical miles<sup>17</sup> does not provide sufficient time to avoid threat aircraft in the majority of collision scenarios. This conclusion became the foundation on which the more empirical methodology of Section 4.1.3 was developed.

### **5.4.2 UAV Battlelab**

The UAV Battlelab proposed an "Air Traffic Detection Sensor System" (ATDSS) initiative dated 9 May 2003. The initiative is based on passive, non-cooperative moving target detection (PMTD) technology developed by Defense Research Associates (DRA)

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<sup>17</sup> Based on an outside study using the Optical Encounter (OPEC) Model at the Air Force Research Labs (AFRL/SN).

in coordination with AFRL/SN (discussed in Section 5.4.3). As cited in the proposal, the three key enabling technologies are

- Advanced target detection algorithms developed at DRA make it possible to extract small targets (intruding aircraft) from digital video data at ranges that far exceed the capability of the human eye.
- High-resolution sensors: Visible band CCD arrays with resolutions of 64 times that of the best production IR arrays are now small fractions of their price.
- High density field-programmable gate arrays provide the means to implement the algorithms while still meeting space, weight, and power constraints associated with UAVs.

The goal of the ATDSS program is to demonstrate its military utility. It is hoped that ATDSS will provide a sense-and-avoid capability to meet the ELOS requirements required by the Predator, Global Hawk, and future Class III ROA in a reliable, cost-effective manner.

### **5.4.3 Air Force Research Lab**

Several organizations within Air Force Research Lab (AFRL) have been working the sense-and-avoid issue from different perspectives. The Operational Encounter (OPEC) model of AFRL Sensor Directorate (AFRL/SN) has been used to quantify human detection capabilities against various aircraft as a function of their paint schemes, sky background, range, sun angles, and other parameters. This conservative assessment, assuming a 90% probability of detection over a 30° by 30° search volume in daylight, predicted a nominal human detection range of 1.6 +/- .2 nm.

In conjunction with this work, AFRL/SNJW is supporting sensor development work in the area of optical flow technology by its subcontractor. This technology holds particular promise due to its low bandwidth requirement and ability to detect non-cooperative traffic. Flight demonstrations on a surrogate UAV aircraft and other analyses are indicating that the concept currently meets Global Hawk and Predator low and medium altitude requirements, the region of most significant threat. These demonstrations have been supported by the modeling and simulation capabilities of the AFRL/SN's Integrated Demonstrations and Applications Laboratory (IDAL). IDAL provides real-time scene rendering capabilities that were applied to risk reduction prior to the flight demonstrations. The Virtual Combat Laboratory (VCL) component of IDAL was used to generate a simulated interaction between a target helicopter (OH58D) and a simulated UAV. The simulation was used to verify engagement geometries and sensor parameters, and to estimate performance.

AFRL Air Vehicles Directorate (AFRL/VA) is supporting efforts to integrate sense-and-avoid capability with flight control software designed by Geneva Aerospace. The Variable Autonomy Control System (VACS) is designed to support UAV operations at various levels of control autonomy. Sensor and avoidance algorithms were used to key the maneuvers during the flight test. AFRL/VA is also contributing to the Autonomous Flight Control Sensing Technology (AFCST) effort, which is intended to define a

common architecture for autonomous sense-and-avoid, air refueling, and auto landing without GPS, among other thrusts.

#### **5.4.4 Program Manager, Air, for Navy Unmanned Air Vehicles (PMA-263)**

The Navy has sponsored several sense-and-avoid flight tests through PMA-263. These efforts involve the Skywatch transponder/receiver, a commercial-off-the-shelf product typically used for general aviation. The Skywatch is discussed in more detail in Section 5.4.5 for its use in another flight test supported by NASA.

PMA-263, in conjunction with the Office of Naval Research (ONR), has also sponsored the Midair Collision Avoidance System (MCAS). The MCAS solution intends to integrate collision avoidance into existing flight critical aircraft transponders. It uses Mode-S signals (ADS-B) and existing antennas and wiring onboard the vehicle to provide passive detection with cooperating aircraft. It establishes a database of other aircraft within the field of view and identifies other aircraft that pose collision threats. The MCAS system development is ongoing, and future plans will incorporate a non-cooperative component to be interoperable with all civilian aircraft.

#### **5.4.5 NASA**

The NASA Environmental Research Aircraft & Sensor Technology (ERAST) program has conducted two non-cooperative detect, see, and avoid (DSA) flight tests. The most recent test was accomplished between March and April 2003 at the Mojave Airport in Mojave, CA. The purpose of the test was to demonstrate the ability of a UAV to detect non-cooperative manned aircraft flying on near-collision trajectories. Once detected, the UAV would perform the appropriate maneuver (if necessary) to avoid the collision. The goal of the maneuver was to maintain a minimum of 500 feet separation.

A manned Scaled Composites Proteus aircraft served as the surrogate UAV. The Proteus was equipped with the Amphitech OASYS (Obstacle Awareness System) radar, 35-GHz all-weather radar technology. The OASYS is a commercial-off-the-shelf system originally designed for helicopters and capable of detecting stationary and moving obstacles. It has the advertised capability to resolve power lines up to 1 nm away in low visibility conditions. During the test, data from the radar was passed to the ground control station so an operator could assess the situation. A Goodrich Skywatch HP traffic advisory system, a passive sensor, was also used to detect cooperative traffic.

Participants for this event included members of the NASA ERAST program, the Navy Air Warfare Center – China Lake, the FAA, and several contractors. The OSD sponsored MARCAT analysis tool provided pre-test analysis to determine the highest risk elements of the flight test. Its predictions were subsequently validated during the actual flight test.

## **5.5 Foreign Aviation Efforts**

### **5.5.1 Australia**

The Civil Aviation Safety Authority (CASA) has developed CASR Part 101 to provide guidance to controllers and manufacturers of UAVs in the operation and construction of UAVs, as well as the means whereby they may safely and legally operate UAV systems. This document also provides guidance to CASA staff on the processing of approvals for UAV operation. UAVs had previously been flown with special permission or as model aircraft until operator certifications began in July 2002. The concept of the Operating Certificate (OC) was introduced to relieve the UAV from meeting the standards associated with Air Operator Certificate (AOC) requirements for manned aircraft.<sup>18</sup>

### **5.5.2 Japan**

The most numerous uses of UAVs and the most successful commercial application of them are for precision agriculture in Japan, where over 1500 unmanned helicopters are currently licensed for use. Driven by a declining, aging farm labor force, Japanese industry developed and successfully marketed unmanned helicopters to spray and plow rice fields. Today in Japan, over 5,500 licensed operators service half a million acres of land each year.

The Japanese Ministry of Agriculture, Forest, and Fisheries (MAFF), along with its affiliated association, the Japanese Agriculture Aviation Association (JAAA), originally promoted the concept of the unmanned helicopter for agricultural purposes. The JAAA, which is supported and audited by the MAFF, establishes safety standards for the areas of flight performance, airframes, and inspection and maintenance. All agricultural helicopters are required to meet these safety standards. In addition, the JAAA also developed an operator flight certification system for unmanned agricultural helicopters and maintains a system to register all vehicles and their customers. All users/operators must receive training and subsequent certification through this system.

### **5.5.3 United Kingdom**

The UK Civil Airspace Authority (CAA) regulatory framework is outlined in the document “Unmanned Air Vehicle Operations in UK Airspace – Guidance.” This document, offered by the Directorate of Airspace Policy, was developed in response to pressure from the UAV community for UAV regulations. Currently, CAA regulations within the United Kingdom require a qualified pilot for any UAV flight in non-restricted airspace. Five classes of UAVs range from Group 1 (intended to be flown in permanently or temporary segregated airspace) to Group 5 (intended to be flown in all airspace classes).

Similar to the requirements for the U.S. military, the CAA framework states that UAVs must “meet the same or better safety and operational standards as manned aircraft.” The lack of recognized airworthiness standards and the lack of S&A capability

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<sup>18</sup> Further information on CASR Part 101 and UAV operator certification requirements is available at <http://www.casa.gov.au/avreg/rules/1998casr/101/index.htm>.

limit the flight of UAVs in the UK. For example, the British Army cannot operate the Phoenix UAV outside of military ranges. The Guidance includes exceptions for small aircraft weighing less than 20 kg (44 lb) so that such vehicles may be primarily flown without airworthiness or aircrew certification for recreational purposes. For larger UAVs up to 150 kg (330 lbs), the Joint Aviation Authority has developed a proposal for small UAVs, “Annex 1: Guidelines for the Regulation of Light UAV Systems.” It addresses such issues as inspection, certification, and operations and includes consideration of the kinetic energy (mass and velocity) of the UAV.

#### **5.5.4 European Community**

UAVNET is a thematic network funded by the European Community to advance the development of UAVs for civilian purposes. The scope of work focuses on

- Bringing together industry, universities, research centers and potential users
- Coordinating a group "cluster" of projects
- Exchange and dissemination of knowledge
- Coordination of activities
- Networking of organizations.

The thematic network serves as a forum for information exchange, for suggesting new policies, and for launching activities in critical technology research. Participants include

Airobotics (Germany)	Nat'l Defense Univ. (Hungary)
Alenia (Italy)	NLR (Netherlands)
BAeSystems (England)	ONERA (France)
Brno Univ. (Czech Rep)	Politecnico Torino (Italy)
CIRA(Italy)	Politechnika Warsaw (Poland)
DLR (Germany)	Sonaca (Belgium)
EADS (France)	Snecma (France)
Gedminas Inst. (Lithuania)	Swedish Space Corp. (Sweden)
IAI (Israel)	Thales (France)
Inst. Of Aviation (Poland)	

USICO is a Critical Technology program under the overall UAVNET effort that is funded by the European Community to improve the safety of civil UAVs and enable their integration within civilian airspace. The more focused scope of USICO addresses the following:

- Recommendations for UAV system airworthiness certification procedures and standards
- Recommendations for UAV operational regulations
- Technology to see and avoid
- Suggestions for research into image recognition and sensors and adapted ADS-B technology
- Flight simulation of UAV ATC/ATM process

Participants from industry include Airobotics, EADS, FHS, IAI, Marconi, and Swedish Space Corporation, as well as three institutes (DLR, NLR, and ONERA) and the University of Naples.



## 6.0 Airspace Integration Plan

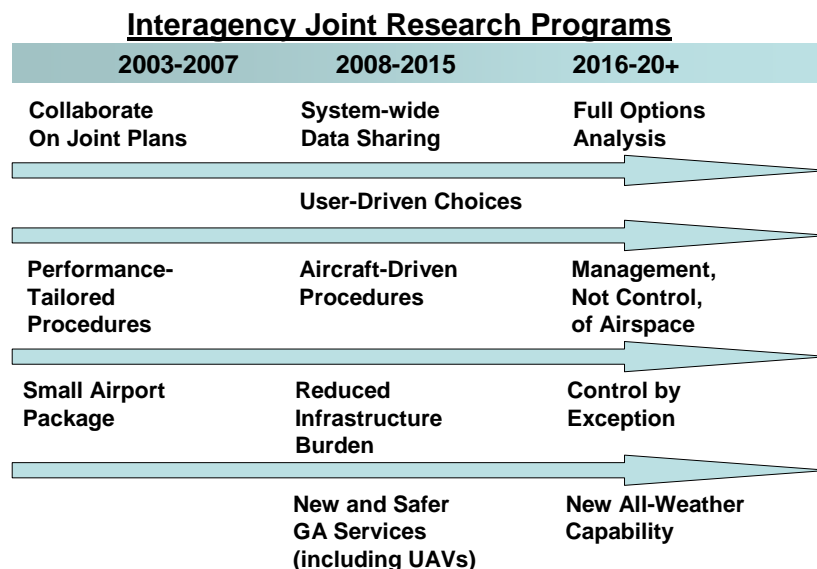
### 6.1 Evolution of the National Airspace System

Based on the regulatory and technology analyses presented above, an Airspace Integration Plan (AIP) for military UAVs can be presented. The purpose of the AIP is to define a coordinated, top-level approach to address the regulatory and technical issues integral to routine military UAV airspace access. The AIP is intended to define those initiatives within the next 5-10 years. Because DoD UAVs are increasingly operating outside of restricted airspace, it is important first to discuss the future of the larger FAA air traffic control infrastructure and how DoD's UAV efforts relate to it.

#### 6.1.1 FAA Airspace Modernization

The long-term FAA plan is “to move away from infrastructure-based systems towards a more autonomous, vehicle-based system” for collision avoidance<sup>19</sup>. Installation of TCAS (see Section 5.3.3) is increasing across the aviation community, and TCAS functionality supports increased operator autonomy. Research and testing of ADS-B (see Section 5.3.2) may afford an even greater capability and affirms the intent of the aviation community to support and continue down this path. Such equipment complements basic see-and-avoid, adds to the situational awareness, and helps provide separation from close traffic in all meteorological conditions.

With respect to airspace modernization, a new joint planning approach to the future air traffic management system is being promoted by the FAA. It includes DoD, NASA, Department of Homeland Security, and the Department of Commerce. The initial Interagency Joint Research Programs, as outlined by the FAA, are shown in Figure 6-1.



<sup>19</sup> 2001 Federal Radionavigation Systems Plan

### **Figure 6-1: FAA Interagency Joint Research Programs**

With the goal of 2025, the Joint ATM Vision is not intended to supplant the more near term objectives of the Operational Evolution Plan (OEP). The OEP is the FAA's rolling 10-year plan to increase the capacity and efficiency of the National Airspace System (NAS) while enhancing safety and security. The commitments and decisions in the OEP have emerged from a close collaboration with the entire aviation community, including the airlines, cargo carriers, airports, manufacturers, general aviation, the Department of Defense, the National Weather Service, and the National Aeronautics and Space Administration, all with a focus on the air transportation services delivered to the flying public. The OEP represents the agreements and commitments of the FAA, DoD and the aviation community to modernize the NAS and solve problems in core areas, or quadrants: Arrival/Departure Rates, En Route Congestion, Airport Weather Conditions, and En Route Severe Weather.

The Joint ATM Vision will also be compatible with the FAA's Flight Plan, 2004-2008. The Flight Plan outlines goals for increased safety, greater capacity, international leadership, and organizational improvements, and is tied to the FAA's budget requests for 2005-2008. With respect to the DoD, implementation efforts will consider national security concerns. As stated in the Flight Plan, the FAA plan is one that "works closely with and supports agencies such as DoD, DHS...that address security risks." The FAA-DoD cooperation encompasses UAV Airspace Integration. Noteworthy in the FAA Flight Plan is the section addressing safety for general aviation, in which the FAA provides guidance to accommodate UAV flight in the National Airspace for the first time. It specifically outlines the following goal:

*Develop policies, procedures, and approval processes to enable operation of unmanned aerial vehicles (UAV).*

In concert with this goal, the DoD is integrally tied to achieving safe and routine military UAV access to the National Airspace. These efforts will likely yield dividends into the civil and commercial domains of the FAA, as well.

#### **6.1.2 DoD and National Airspace System Evolution**

The Department of Defense is a critical stakeholder in the National Airspace System (NAS) redesign. DoD is a major user and service provider partner along with the FAA. As a service provider, the DoD is involved in airspace redesign. NAS redesign affects air traffic procedures, airspace usage, and may require changes in equipment. The DoD mission is integrated in these changes.

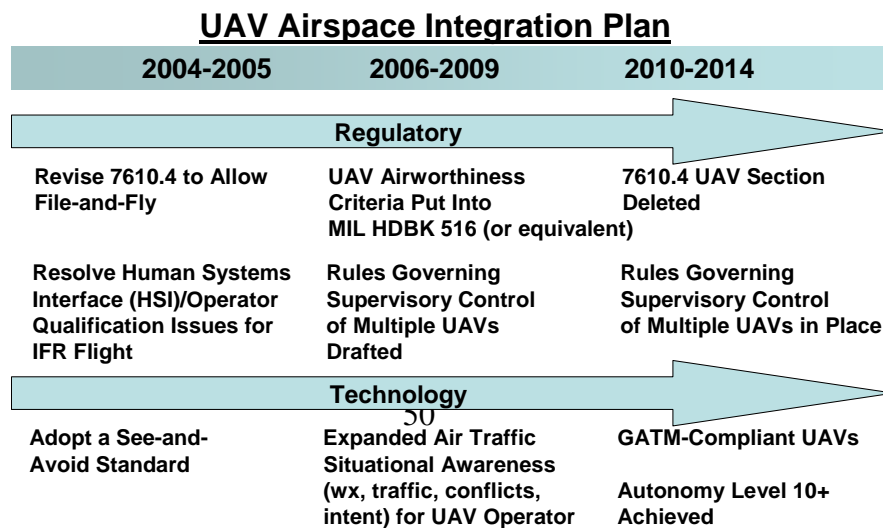
On 19 March 2002, a Memorandum of Agreement was signed between the FAA and DoD. The purpose of this Memorandum of Agreement (MOA), *DoD-FAA National Airspace System Integration*, was to establish a framework for DoD Integration into the FAA National Airspace System (NAS) Modernization process. This MOA was created by the DoD-FAA NAS Integration Subgroup and resulted in a set of specific actions necessary to transition DoD operational requirements into the NAS. It includes mutually agreed-to resolutions for each action.

With respect to its UAV Airspace Integration Plan, DoD will review the FAA modernization efforts in their current form, and as they evolve, identify any impacts to DoD in terms of airspace, equipment, procedures, and system access for its UAVs. Specific goals to be achieved include the following:

- Each military Service will determine specific impacts of the FAA's plans to their UAV training and operations.
- Each military Service, in the context of its UAV training and operations, will identify those areas within the FAA's OEP and ATM Vision that 1) can be implemented without impact, 2) can be accommodated if mitigating actions are taken, and 3) are not acceptable along with the rationale supporting the position.
- DoD will support the development of UAV-specific, consensus-based standards in order to facilitate the creation of UAV regulations. This, in turn, will facilitate military UAV access to the National Airspace System.

DoD should continue to coordinate with the FAA to ensure that plans accommodate military UAV requirements and allow adequate transition time for integration of military mission needs. As noted in the MOA, the DoD will take into account, in its subsequent review of FAA airspace initiatives, the FAA's need to meet the growing demand on the National Airspace System by civil and commercial users.

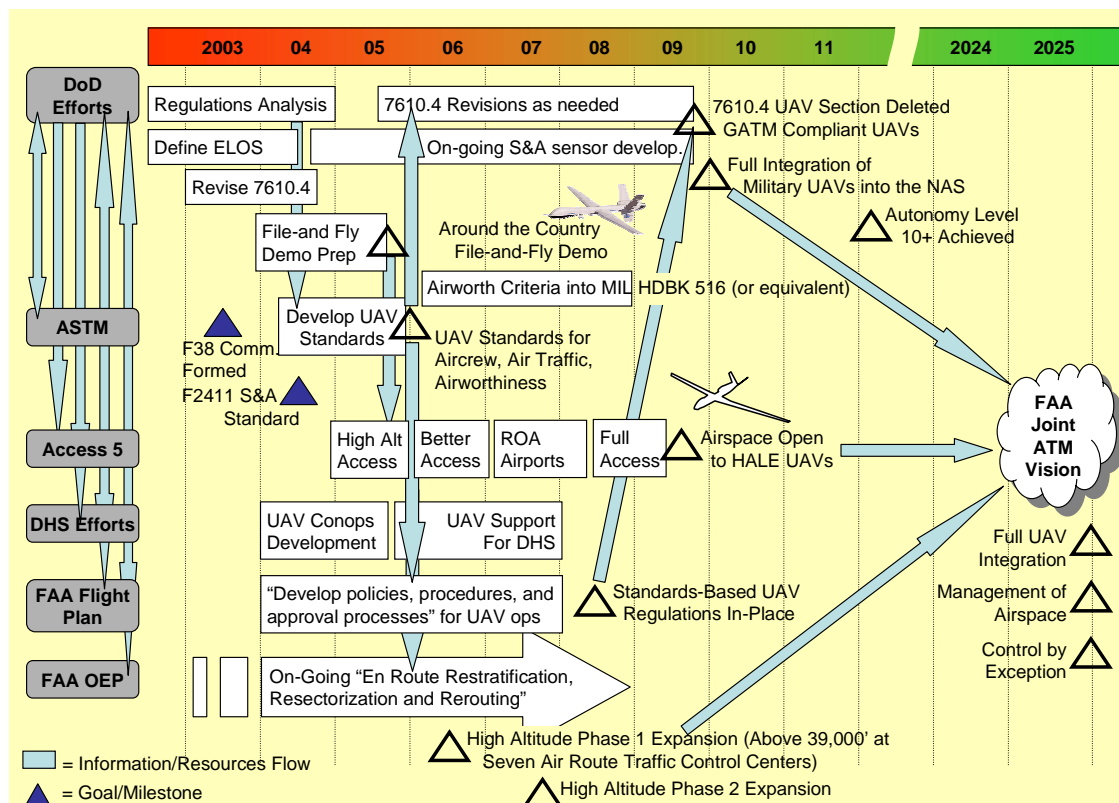
Figure 6-2 charts an achievable timeline for several key regulatory and technology goals for integration of unmanned with manned aviation over the coming decade. It is intended to develop in parallel with the larger FAA vision to facilitate routine military UAV flights in the United States.



**Figure 6-2: UAV Airspace Integration Top-Level Plan**

The status of FAA Order 7610.4, as indicated in Figure 6-2, is a key barometer to judge the progress of this effort. The intent of the current version, 7610.4K, is to require the military to obtain a Certificate of Authorization to fly ROA in the National Airspace. A DoD ROA Working Group goal is that FAA Order 7610.4L will permit file and fly operations by “qualified” UAVs (Cat III ROA) for the first time; other UAVs will still have to follow the COA process. In this context, “qualified” means equipped with or using an approved sense-and-avoid capability, and properly equipped for the class of airspace in which it is to operate. As the decade progresses and subsequent revisions of FAAO 7610.4 are issued, sense-and-avoid technology will potentially allow its UAV section to evolve away from the COA process. Within a decade, FAAO 7610.4 should no longer need to distinguish between manned and unmanned flight; its ROA section can perhaps be deleted.

The DoD’s airspace efforts will support and be leveraged by other organizations seeking to normalize ROA airspace access. The planned role of the DoD within the larger UAV community for airspace integration is shown in Figure 6-3 below. When available, milestones and timelines associated with the plans are also indicated.



**Figure 6-3: ROA Airspace Integration Milestones**

## **6.2 *ROA in the National Airspace***

The migration of the NAS from ground based traffic control to airborne traffic management, scheduled to occur over the next decade, will have significant implications for ROA. Sense-and-avoid will become an integrated, automated part of routine position reporting and navigation functions by relying on a combination of Automatic Dependent Surveillance-Broadcast (ADS-B) and Global Positioning System (GPS). In effect, it will create a virtual bubble of airspace around each aircraft so that when bubbles contact, avoidance is initiated. All aircraft will be required to be equipped to the same level, making the unmanned or manned status of an aircraft transparent to both flyers and to the FAA.

With respect to regulations, Table 6-1 summarizes the current FAA regulations that could be applied to ROA to allow more routine access to the NAS, as discussed in section 3.1.

**Table 6-1: Alignment of ROA Categories with FAA Regulations**

		<b>Certified Aircraft / Cat III ROA<sup>20</sup></b>	<b>Non-Standard Aircraft / Cat II ROA</b>	<b>RC Model Aircraft / Cat I ROA</b>
<b>FAA Regulation</b>		14 CFR 91	14 CFR 91, 101, and 103	None (AC 91-57)
Airspace Usage		All	Class E, G, & non-joint-use Class D	Class G (<1200 ft AGL)
Airspeed Limit, KIAS		None	NTE 250 (proposed)	100 (proposed)
<b>Example Types</b>	Manned	Airliners	Light-Sport	None
	Unmanned	Predator, Global Hawk	Pioneer, Shadow	Dragon Eye, Raven

The terms within Table 6-1 are further defined below.

- **ROA – Cat III:** capable of flying throughout all categories of airspace and conforms to Part 91, etc. (i.e., all the things a regulated manned aircraft must do including the ability to “sense-and-avoid”). Airworthiness and operator certification are required. ROA are generally built for beyond line-of-sight operations.

Examples: Global Hawk, Predator

- **ROA – Cat II:** non-standard aircraft that perform special purpose operations. Operators must provide evidence of airworthiness and operator qualification. Cat II ROA may perform routine operations within a specific set of restrictions.

Examples: Pioneer, Shadow

- **ROA – Cat I:** analogous to RC models as covered in AC 91-57. Operators must provide evidence of airworthiness and operator qualification. Small UAVs are generally limited to visual line-of-sight operations.

Examples: Pointer, Dragon Eye

### **6.3 OSD UAV Roadmap Goals for Airspace**

The following goals for UAV airspace integration are drawn from the *OSD UAV Roadmap, 2002-2027*.

<sup>20</sup> Some Cat III ROA may only be certified to operate under VFR.

- Coordinate revising FAA Order 7610.4 to replace the requirement for using the COA process for all UAVs with one for using the DD175 form DoD Flight Plan for qualifying UAVs (Cat III ROA).
- Work with the FAA to define appropriate conditions and requirements under which a single operator would be allowed to control multiple airborne UAVs simultaneously.
- Document and disseminate any UAV-unique lessons learned from certifying the Global Hawk as airworthy by means of the OSS&E process. Formal documentation as a DoD Instruction for guiding future UAV airworthiness certifications should be considered.
- Ensure Service efforts for developing and evaluating automated sense-and-avoid and collision avoidance systems are coordinated and non-duplicative.
- Equip DoD UAVs intended for Instrument Flight Rules (IFR) operations with a stand-alone, hot backup, ground-based navigation system and establish a standardized lost link procedure.
- Decrease the annual mishap rate of larger model UAVs (ROA – Cat III) to less than 20 per 100,000 flight hours by FY09 and less than 15 per 100,000 flight hours by FY15.

These were developed based on lessons learned from on-going airspace integration work as well as anticipated needs within the user community. Achieving the specific goals will be critical to the seamless integration of UAVs into military and/or civil airspace.

## **6.4 Summary**

A summary of the regulatory and technical topics discussed in this plan as efforts related to the integration of ROA into the NAS is provided below.

### Regulatory

- No changes to 14 CFR are required; they can be applied to ROA.
- FAA Order (FAAO) 7610.4 procedures enable airspace access for non-compliant aircraft. Changes to FAAO 7610 are needed, and are in process, to recognize compliant ROA.
- Standards supporting ROA-specific airworthiness and training are in place, or being developed.
- The evolution of the National Airspace System will create opportunities that should facilitate ROA integration. Coordination between the FAA and DoD is necessary to ensure safety and national defense requirements are satisfied.

- Civil and commercial ROA airspace integration efforts reduce costs and promote improved access for the DoD by enabling broader commercial and public use.

#### Technical

- A standard has been developed defining sense-and-avoid system performance.
- A suitable sense-and-avoid capability is required in order for ROA/UAVs to comply with 14 CFR 91.113 without using manned chase aircraft.
- Sense-and-avoid systems need to find and avoid traffic conflicts within plus or minus 110 degrees in azimuth measured from the longitudinal axis and plus or minus 15 degrees in elevation from the cruise speed level line.
- Other, non-14 CFR, but UAV-unique technical capabilities will be required under DoD jurisdiction. These include suitable C2 data links and voice communication with ATC.





## Appendix A: FAA Form 7711-2 Certificate of Waiver or Authorization

One of several uses for FAA form 7711-2 is to apply for a Certificate of Authorization to fly Remotely Operated Aircraft in the National Airspace System. It is provided here as a reference.

### CERTIFICATION OF WAIVER OR AUTHORIZATION APPLICATION - PRIVACY ACT

The information on the accompanying form is solicited under authority of Federal Aviation Regulations Parts 91, 101, and 105.

Submission of the information is mandatory.

The purpose of this information is to establish eligibility for certificate of waiver or authorization

The data will be used for recordkeeping and statistical purposes.

Incomplete submission may result in delay or denial of your request.

FAA Form 7711-2 (6-86) Supersedes Previous Edition

**DETACH THIS PART BEFORE USING**

No certificate may be issued unless a completed application form has been received (14 C.F.R. 91, 101, and 105).

<b>APPLICATION FOR CERTIFICATE OF WAIVER OR AUTHORIZATION</b> US Department of Transportation Federal Aviation Administration	<i>Form Approved: O.M.B. No. 2120-0027</i>	
	APPLICANTS - DO NOT USE THESE SPACES	
	Region	Date
	Action Approved Disapproved - <i>Explain under "Remarks"</i>	
	Signature of authorized FAA representative	
<b>INSTRUCTIONS</b> Submit this application in triplicate (3) to any FAA Flight Standards district office. Applicants requesting a Certificate of Waiver or Authorization for an aviation event must complete all the applicable items on this form and attach a properly marked 7.5 series Topographic Quadrangle Map(s), published by the U.S. Geological Survey (scale 1:24,000), of the proposed operating area. The map(s) must include scale depictions of the flightlines, showlines, race courses, and the location of the air event control point, Police dispatch, ambulance, and fire fighting equipment. The applicant may also wish to submit photographs and scale diagrams as supplemental material to assist in the FAA's evaluation of a particular site. Application for a Certificate of Waiver or Authorization must be submitted 45 days prior to the requested date of the event. Applicants requesting a Certificate of Waiver or Authorization for activities other than an aviation event will complete items 1 through 8 only and the certification, item 15, on the reverse.		
1. Name of organization	2. Name of responsible person	
3. Permanent mailing address House number and street or route number City State and ZIP code Telephone No.		

4. FAR section and number to be waived			
5. Detailed description of proposed operation ( <i>Attach supplement if needed</i> )			
6. Area of operation ( <i>Location, altitudes, etc.</i> )			
7a. Beginning ( <i>Date and hour</i> )		b. Ending ( <i>Date and hour</i> )	
Aircraft make and model (a) 8.	Pilot's Name (b)	Certificate number and rating (c)	Home address ( <i>Street, City, State</i> ) (d)

**FAA Form 7711-2 (6-86) Supersedes Previous Edition FAA Form 7711-2 (6-86)  
Supersedes Previous Edition**

9. The air event will be sponsored by: <i>ITEMS 9 THROUGH 14 TO BE FILLED OUT FOR AIR SHOW/AIR RACE WAIVER REQUESTS ONLY.</i>
mailing address House number and street or route number City State and ZIP code Telephone No. 10. Permanent
11. Policing ( <i>Describe provisions to be made for policing the event.</i> )

12. Emergency facilities <i>(Mark all that will be available at time and place of air event.)</i> Physician Ambulance Crash wagon Fire truck Other -Specify		
13. Air Traffic control <i>(Describe method of controlling traffic, including provision for arrival and departure of scheduled aircraft.)</i>		
Hour (a)	Date (b) 14. Schedule of Events <i>(include arrival and departure of scheduled aircraft and other periods the airport may be open.)</i>	Event (c)
Please Read	The undersigned applicant accepts full responsibility for the strict observance of the terms of the Certificate of Waiver or Authorization, and understands that the authorization contained in such certificate will be strictly limited to the above described operation. <i>If sufficient space is not available, the entire schedule of events may be submitted on separate sheets, in the order and manner indicated above.</i>	
15. Certification - I CERTIFY that the foregoing statements are true.		
Date Signature of Applicant		
Remarks		



## **Appendix B: FAA Order 7610.4K, Chapter 12, Section 9**

(Effective February 19, 2004)

### **REMOTELY OPERATED AIRCRAFT (ROA)**

#### **12-9-1. OPERATION**

**a.** ROA Operations should normally be conducted in the following areas:

- 1.** Within Restricted Areas.
- 2.** Within Warning Areas.

**b.** For those operations that cannot be contained wholly within Restricted Areas or Warning Areas, the ROA operations shall be conducted in accordance with procedures outlined in paragraph [12-9-2](#), Procedures.

**NOTE-**

*Procedures for nonjoint-use DOD airfield operations will be as specified by DOD.*

#### **12-9-2. PROCEDURES**

ROAs operating outside Restricted Areas and Warning Areas shall comply with the following:

**a.** At least 60 days prior to the proposed commencement of ROA operations, the proponent shall submit an application for a Certificate of Authorization (COA) to the Air Traffic Division of the appropriate FAA regional office. COA guidance can be found in FAA Handbook [7210.3](#), Facility Operation and Administration, Part 6, Chapter 18, Waivers, Authorizations, Exemptions, and Flight Restrictions. The following documentation should be included in the request:

**NOTE-**

*In the event of real-time, short notice, contingency operations, this lead time may be reduced to the absolute minimum necessary to safely accomplish the mission.*

- 1.** Detailed description of the intended flight operation including the classification of the airspace to be utilized.
- 2.** ROA physical characteristics.
- 3.** Flight performance characteristics.
- 4.** Method of pilotage and proposed method to avoid other traffic.

**NOTE-**

*Approvals for ROA operations should require the proponent to provide the ROA with a method that provides an equivalent level of safety, comparable to see-and-avoid requirements for manned aircraft. Methods to consider include, but are not limited to; radar observation, forward or side looking cameras, electronic detection systems, visual*

*observation from one or more ground sites, monitored by patrol or chase aircraft, or a combination thereof.*

5. Coordination procedures.
6. Communications procedures.
7. Route and altitude procedures.
8. Lost link/mission abort procedures.
9. A statement from the DOD proponent that the ROA is airworthy.

**NOTE-**

*The proponent should ensure that the ROA contains a means to safely terminate the flight, follow specified and defined procedures for mission abort, or proceed in accordance with specific flight termination procedures.*

**b.** COAs shall have an effective date with a duration not to exceed 1 year unless renewed or revalidated. The COA expires on the stated termination date, unless sooner surrendered by the proponent, or revoked by the issuing agency.

**c.** ROAs shall be equipped with standard aircraft anti-collision lights in accordance with criteria stipulated in 14 CFR Section 23.1401. These lights shall be operated during all phases of flight in order to enhance flight safety.

**d.** ROAs shall be equipped with an altitude encoding transponder that meets the specifications of 14 CFR Section 91.215. The transponder shall be set to operate on a code assigned by air traffic control. Unless the use of a specific, special-use code is authorized, the ROA pilot-in-command shall have the capability to reset the transponder code while the ROA is airborne. If the transponder becomes inoperative, at the discretion of the affected region or air traffic facility, the mission may be canceled and/or recalled.

**e.** Instantaneous two-way radio communication with all affected ATC facilities is required. For limited range, short duration flights, proponents may request relief from radio requirements provided a suitable means of alternate communication is available. Compliance with all ATC clearances is mandatory.

**f.** The proponent and/or its representatives shall be noted as responsible at all times for collision avoidance maneuvers with nonparticipating aircraft and the safety of persons or property on the surface.

## **Appendix C: AC 91-57 - Model Aircraft Operating Standards**

Advisory Circular 91-57  
DATE June 9, 1981

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration  
Washington, D.C.

Subject: MODEL AIRCRAFT OPERATING STANDARDS

1. PURPOSE. This advisory circular outlines, and encourages voluntary compliance with, safety standards for model aircraft operators.
2. BACKGROUND. Modelers, generally, are concerned about safety and do exercise good judgment when flying model aircraft. However, model aircraft can at times pose a hazard to full-scale aircraft in flight and to persons and property on the surface. Compliance with the following standards will help reduce the potential for that hazard and create a good neighbor environment with affected communities and airspace users.
3. OPERATING STANDARDS.
  - a. Select an operating site that is of sufficient distance from populated areas. The selected site should be away from noise sensitive areas such as parks, schools, hospitals, churches, etc.
  - b. Do not operate model aircraft in the presence of spectators until the aircraft is successfully flight tested and proven airworthy.
  - c. Do not fly model aircraft higher than 400 feet above the surface. When flying aircraft within 3 miles of an airport, notify the airport operator, or when an air traffic facility is located at the airport, notify the control tower, or flight service station.
  - d. Give right-of-way to, and avoid flying in the proximity of, full-scale aircraft. Use observers to help if possible.
  - e. Do not hesitate to ask for assistance from any air traffic control tower or flight service station concerning compliance with these standards.

R. J. VAN VUREN  
Director, Air Traffic Service

Initiated by: AAT-220





## **Appendix D: Defense Contract Management Agency INST 8210.1: UAV Pilot Qualifications**

The following excerpts are taken from the DCMA Instruction 8210.1. They describe minimum qualifications for approval of contractor crewmembers (pilots/operators) for test and other flight categories of UAVs.

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3.6. UAV Pilot Qualifications. All UAV pilots must be approved in writing by the Government Flight Representatives (GFR) prior to operating any aircraft under the G&FRC/AFRC, and shall be sufficiently qualified to make certain he/she can operate the UAV in a safe and effective manner. No one shall serve as pilot/pilot-in-command for two or more UAVs simultaneously.

3.6.1. UAV pilots operating *exclusively* in Restricted or Warning airspace, as designated in DoD Flight Information Publications and DOT/FAA aeronautical charts, shall hold ratings and qualifications consistent with specific contractual wording, or Service requirements for UAVs/ROAs. If Service/contractual guidance does not exist, then the GFR shall approve/disapprove UAV pilots/operators based upon the requirements of paragraph 3.6.2. below.

3.6.2. UAVs operating outside of Restricted or Warning airspace shall do so only under an FAA MOU/MOA or similar document. UAV pilots operating UAVs outside of Restricted or Warning airspace shall: hold at least a private pilot's certification; an instrument rating; pass an annual instrument review; and have a total of 300 flight hours as pilot-in-command or Mission Commander (UAVs or aircraft) - 100 of which must be in a manned aircraft; hold a current FAA UAV pilot certification (when such a certification exists); and comply with Service Guidance concerning pilot qualifications/currencies if more restrictive than either of the above requirements.



## Appendix E: AC 25.773-1: Pilot Compartment View Design Considerations

AC Number: AC 25.773-1

Date: 01/08/93

Subject:  
Pilot Compartment View Design Considerations

Related Regulation(s):  
Part 25

Section Number(s):  
Unknown Section

Cancels:

Initiating Office:  
ANM-111

AC Document in PDF Format:

AC Document:

**Subject:** Pilot Compartment View Design Considerations

**1. PURPOSE.** This advisory circular (AC) sets forth a method for demonstrating compliance with the airworthiness standards for transport category airplanes pertaining to pilot compartment view. As with all AC material, it is not mandatory and does not constitute a regulation. It is for guidance purposes only.

### **2. RELATED DOCUMENTS.**

a. Federal Aviation Regulations (FAR). The related sections of Part 25 include:

Section 25.237 Wind velocities  
Section 25.773 Pilot compartment view  
Section 25.775 Windshields and windows  
Section 25.777 Cockpit controls (seat for pilots from 5'2" to 6'3" in height, in consideration of the design eye position).

b. Industry Documents. The following documents are available from the Society of Automotive Engineers, Inc. (SAE), 400 Commonwealth Drive, Warrendale, PA 15096:

ARP 268G Location and Actuation of Flight Deck Controls for Transport Airplanes.

ARP 4101/1 Seats and Restraint Systems for the Flight Deck.

ARP 4101/2 Pilot Visibility from the Flight Deck.

### **3. BACKGROUND.**

a. On January 19, 1971, the FAA issued Notice of Proposed Rulemaking No. 71-2, Cockpit Vision and Cockpit Controls. This notice proposed amendments to the airworthiness standards for transport category airplanes that introduced comprehensive cockpit vision standards and changed the range of pilot heights used for the location and arrangement of cockpit controls. A majority of the commenters responding to Notice 71-2 objected to the proposed amendments. In general, the airplane manufacturers believed the proposed requirements were too stringent and exceeded the state-of-the-art, particularly with respect to the size of transparent panels, considering weight and structural strength necessary to provide clear vision in the specified areas. The manufacturing industry, represented by the Transport Airworthiness Requirements Committee (TARC) of the Aerospace Industries Association, maintained that the proposed size of the clear vision field was in excess of that required to meet the most important objective of the proposed standards. That objective was to provide optimum vision for avoidance of mid-air collisions in "see and be seen" conditions of flight. The committee carried out a computerized study program that considered 10,000,000 hypothetical cases of pairs of airplanes on collision courses considering reasonable airplane mixes of type, speed, flight path angles, bank angles, etc. In addition, all known available data from actual mid-air collisions, reported near misses, and USAF Hazardous Air Traffic Reports (HATR) were used.

b. The pilot compartment view that evolved from the TARC study was somewhat smaller and its area redistributed in comparison with existing CAM 4b.350 recommendations and those proposed in Notice 71-2. The FAA withdrew the proposed rulemaking based on the information presented. Subsequent to that withdrawal, the Society of Automotive Engineers Inc. (SAE), Committee S-7, adopted the TARC recommendation as Aerospace Standard AS 580B. The FAA has adopted the TARC/SAE pilot compartment view for this advisory circular. Some of the SAE criteria have been modified and adopted as guidance for validating the pilot compartment view. Users of this circular should bear in mind that the pilot compartment view described herein is that which the TARC study showed to be minimum for collision avoidance. Designers are urged to provide the maximum practicable capability in excess of this field of view.

c. It is the responsibility of the applicant to show by acceptable means that the proposed arrangement meets the requirements of accessibility and non-interference set forth by Section 25.777. Designers and certification authorities are encouraged to refer to guidance in current Aerospace Recommended Practice ARP 268G and ARP 4101/1 (replaces AS 290B) for these considerations. These documents were also prepared by the SAE for use in conjunction with ARP 4101/2 (replaces AS 580B).

#### 4. CRITERIA FOR PILOT COMPARTMENT VISIBILITY.

a. The flight deck windshield must provide sufficient external vision to permit the pilot to safely perform any maneuvers within the operating limits of the aircraft and, at the same time, afford an unobstructed view of the flight instruments and other critical components and displays from the same eye position. The following subparagraphs describe the minimum criteria for pilot compartment view. Aircraft designers and manufacturers should make every effort to build windshields that offer the pilot more external vision.

b. Design Eye Position. The design eye position is a single point selected by the applicant that meets the requirements of Sections 25.773(d) and 25.777(c) for each pilot station. Figure 1 depicts a design eye position and pilot compartment view for optimum collision avoidance potential for the left pilot seat. For the right pilot seat, all left/right dimensions are reversed.

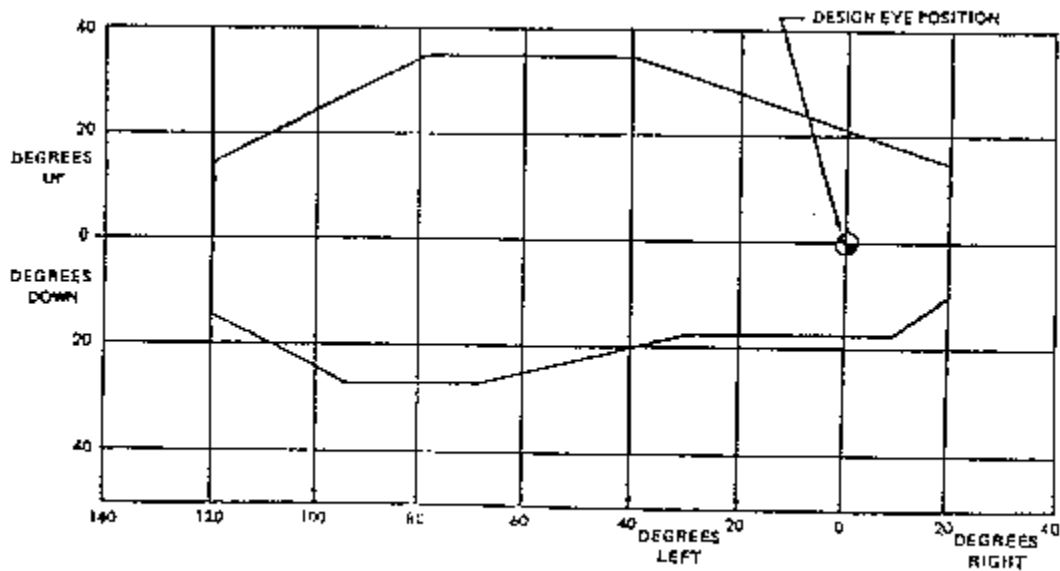


Figure 1. Pilot Compartment View

**Figure 1. Pilot Compartment View**

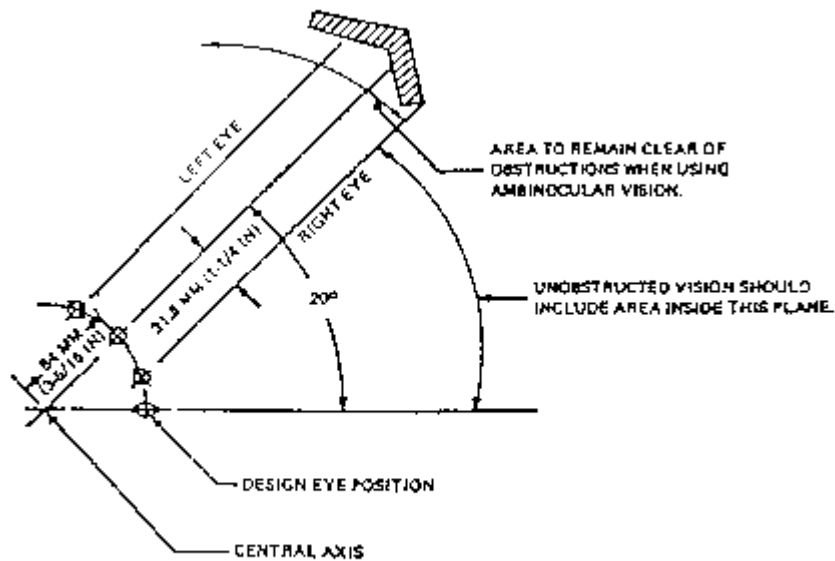


Figure 2. Measurement of Angles

### Figure 2. Measurement of Angles

c. Clear Areas of Vision. The clear areas of vision should be determined by measurement of angles from the design eye position utilizing ambinoocular vision. Ambinoocular vision is the total area that can be seen by both eyes. It is not limited to the binocular field but includes, in addition, monocular regions visible to the right eye, but not to the left, and vice versa. Measurements are made as depicted in figure 2 with an intraocular distance of 63.6 mm (2 1/2 inches) and utilizing rotational motion in a horizontal plane about a central axis 84 mm (3 5/16 inches) aft of the design eye position. These dimensions correspond to average cranial dimensions for humans. The horizontal and vertical vision angles should be measured from:

- (1) a vertical datum plane running fore and aft through the design eye point and central axis; and
- (2) a horizontal datum plane perpendicular to the vertical plane that also passes through the design eye point and central axis.

The vertical and horizontal datum planes are fixed relative to the airplane and should be parallel to those corresponding to zero pitch and yaw angles for the airplane. With the design eye position located per paragraph 4b, the vision through the transparent areas should provide the following pilot compartment view:

- (1) Forward and up 35 degrees from the horizontal datum plane at 40 degrees left of the vertical datum plane, diminishing linearly to 15 degrees up at 20 degrees right.
- (2) Forward and down 17 degrees from the horizontal datum plane between 30 degrees

left and 10 degrees right of the vertical datum plane, diminishing linearly to 10 degrees down at 20 degrees right.

(3) Forward and up 35 degrees from the horizontal datum plane between 40 degrees left and 80 degrees left of the vertical datum plane, diminishing linearly to 15 degrees up at 120 degrees left.

(4) Forward and down 17 degrees from the horizontal datum plane at 30 degrees left of the vertical datum plane, diminishing linearly to 27 degrees down at 70 degrees left.

(5) Forward and down 27 degrees from the horizontal datum plane between 70 degrees left and 95 degrees left of the vertical datum plane, diminishing linearly to 15 degrees down at 120 degrees left.

d. Landing Vision. In addition to the requirements of paragraph 4c, the view angle forward and down should be sufficient to allow the pilot to see a length of approach and/or touch-down zone lights that would be covered in three seconds at landing approach speed when the aircraft is:

(1) On a 2 1/2 degree glideslope.

(2) At a decision height that places the lowest part of the aircraft at 30.5 m (100 feet) above the touch-down zone extended horizontally.

(3) Yawing to the left to compensate for ten knots crosswind.

(4) Loaded to the most critical weight and center of gravity.

(5) Making the approach with 366 m (1200 feet) runway visual range (RVR).

e. Obstructions to Vision.

(1) There should be no obstructions to vision between 20 degrees right and 20 degrees left in the vision polar depicted by figure 1. Obstructions outside this 40 degree area should be kept to a minimum; ideally not more than three (i.e., center post, forward post, and side post). Using ambinocular vision, it should be possible for a pilot to have vision of any given bearing that is blocked to the other pilot from 80 degrees right to 80 degrees left of the design eye position. In addition, it is desirable that obstructions be eliminated by using ambinocular vision with the average human intraocular dimensions of 63.6 mm (2 1/2 inches). This would require that the projected width of the obstruction be no greater than the intraocular dimension. It should be possible for the pilot to eliminate any obstruction to vision using ambinocular vision with head movement of 13 mm (1/2 inch) left and right. In the example depicted in figure 2, head movement to the left would eliminate the obstacle. Use of sun visors that reduce light transmissivity are acceptable; however, totally opaque visors that impinge upon the field of view of figure 1 should not be used.



(2) Windows and windshields that have become deteriorated in service are considered to be airworthy only if the pilot compartment view is not impaired below the criteria set forth in paragraph e(1).

f. Optical Properties. The windshield should exhibit optical properties equivalent to those specified in MIL-P-25374B for plastic windows, and MIL-G-25871B for glass or glass-plastic windows. These documents contain information on laminate construction, optical uniformity, luminous transmittance, physical properties, environmental exposure, etc.

g. Precipitation. Precipitation clearing should be provided for the windshield panels directly forward of each pilot and should be effective at all thrust settings up to at least 1.6 V sub s (clean) or 230 knots, whichever is less. The minimum area to be cleared should be 15 degrees left to 15 degrees right of the design eye position, upward to the horizon during the steepest approach path expected in operation, and downward to the limits recommended in paragraph 4c. If windshield wipers are used, wiper speeds of approximately two sweeps per second have been found to be satisfactory in maintaining a cleared area.

h. Compliance Considerations. A method traditionally used for showing compliance with the viewing requirements has been a somewhat exotic camera system. Other methods are also allowed, including 3-D graphics systems and simple surveying equipment. The formation of the vision boundaries described in this advisory circular is based on flight at subsonic speeds. Any aircraft featuring variable nose geometry, or those capable of making STOL/VSTOL steep approaches, should be subject to special compliance considerations.

/s/ DAVID G. HMIEL

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